EVALUATION OF SMALLHOLDER PIG PRODUCTION AND MARKETING SYSTEMS IN RELATION TO PORCINE CYSTICERCOSIS IN MBEYA REGION, TANZANIA

BY

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ABSTRACT

Four studies were conducted to evaluate smallholder pig production and marketing systems in relation to porcine cysticercosis (PC) in Mbeya region, Tanzania. In study one, a topical Participatory Rural Appraisal (PRA) method was used to characterize production systems. The study involved 279 pig-keeping households in nine villages of Mbozi and Mbeya rural districts. In study two, a cross sectional survey was used to collect data on pig production, marketing, and prevalence of PC from a random sample of 300 pig-keeping households in 30 villages of the same districts. Concurrently, 600 pigs from the sampled households were examined for PC using lingual examination and Antigen-ELISA tests. In study three, a longitudinal design involving 40 pig-keeping households in 10 villages of the two districts was conducted to examine pig production and marketing dynamics between seasons. In study four, a cross sectional survey using structured questionnaires was used to collect data from 124 randomly sampled pig traders in Mbozi, Mbeya rural and Mbeya urban districts.

Mean land size per household was 2.0 ha. Pig keepers in Mbozi district had significantly bigger land (2.6± 0.2 ha, $P<0.001$) and pig herd sizes (5.5± 4.7, $P < 0.05$) than those in Mbeya rural. Age, marital status, household size, and land size had significant influence on pig herd size ($P < 0.05$). Three pig management systems were practised, namely; total confinement (TC), semi confinement (SC) and free range/herding (FRH). TC and SC were the dominant systems practised by 42 and 49 % of pig keepers, respectively. Household socio-economic factors and seasons of the year had varying influence on distribution of pig management systems. Majority (93 %) of pig keepers were aware of PC, but only 23.2 % of them had knowledge on how pigs were infected. PC affected all study villages. Household level prevalence varied between 10 and 90% with mean of 45.3 %. Risk factors for PC prevalence were; FRH and SC (OR=2.1, $P< 0.01$), poor pig shelter (OR = 8.4, $P< 0.05$), previous experience of PC in the pig herd (OR = 2.6, $P < 0.01$) and sourcing of water from rivers (OR=3.1, $P< 0.001$,) and ponds (OR = 5.0, $P< 0.05$). The important risk behaviours for PC prevalence in pig marketing system were; the dominancy of informal marketing channels, inadequate and poor slaughter facilities and inadequate inspection services.

It is concluded that the smallholder pig production has the potential to increase productivity, profitability, and thus improving livelihood of smallholder farmers if suitable and sustainable policies and technological innovations are developed and implemented. Research, development, and promotion of integrated approaches and combination of simple and cost effective interventions are recommended.

DECLARATION

I, ELIAKUNDA CASMIR KIMBI, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and has not been submitted for a degree award in any other institution.

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My sincere hope is that this work will be practically connected to the improvement of smallholder pig production, marketing, and control of porcine cysticercosis in Tanzania and other countries of similar environment. The significance and generous contributions of all people and institutions mentioned above notwithstanding, the final responsibility for this work rests on me.

DEDICATION

This work is dedicated to my loving parents: my father *Mzee* Casmir Konini Kimbi who passed away before the dreams of this work could be realised, and my mother *Mama* Pudensiana Casmir Kimbi.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

The demand for meat in Sub Saharan Africa (SSA) and Tanzania in particular has been steadily increasing in recent years; the increase in demand has been attributed mainly to the growth in human population, urbanization, and income (Delgado *et al.*, 1999; TBS, 2003; FAO, 2005; UN, 2008). On the other hand, the current food crisis in SSA and Tanzania in particular has negatively affected the supply of animal protein food, especially meat, and thus caused an increase in meat prices (FAO, 2008a). Meat production in Tanzania has mainly relied on ruminant livestock especially beef. However, future meat production from ruminants is unlikely to meet anticipated demand since these animals have longer reproductive cycles and lower prolificacy than most mono-gastric animals. Furthermore, in response to increased population pressure, good pasture land is being converted into crop land, leaving increasingly poorer areas for grazing and mixed farming. Annual growth rate of meat production from beef in Tanzania, declined from an average of 4.7 % during 1980-1990 to 1.4 % during 1990-2000 (FAO, 2005; Ndikumana and Kamidi, 2005; FAOSTAT, 2007). Between 2000 and 2005 the increment was at lower rate of only 0.2 % per annum (FAO, 2005; FAOSTAT, 2007). These trends necessitate the establishment of suitable strategies for alleviating the anticipated scarcity of meat in the near future. One option is to develop efficient livestock production systems with high turnover rate, i.e. livestock systems with short reproductive cycles and more efficient than ruminants in converting feed resources into meat.

Pig production had been earlier advocated and recommended as an alternative source of meat to cope with growing demand for meat in SSA countries due to its short generation interval, high prolificacy, and growth rate (FAO, 2001; Delgado and Clare, 2003). Pig and poultry meat are expected to provide nearly one-half of the meat requirements for SSA, estimated at eight million (42 %) of the total 19 million tonnes of meat to be required annually by the year 2025 (WI, 1992). Moreover, the pig subsector has been identified as a prominent growing sector of developing countries' agriculture with an annual growth of 6.1% compared to 5.4, 5.3, 3.6, and 2.4% for fish, vegetable, fruits, and cereals, respectively (Danielle, 2003).

In Tanzania, pig production has increased considerably in the last decades coupled with increased pork consumption in both rural and urban areas (URT, 2006; FAOSTAT, 2009). Pig production in the country is mainly (about 90 %) carried out by smallholder pig keepers under low input-output production systems, though, with an important role in securing livelihoods and nourishment to rural, peri-urban, and urban families (Lekule *et al.*, 1983; Mbaga *et al.*, 2003; URT, 2006; Mwakasendo *et al.*, 2006). Regardless of the low input-output relationship, existing production systems have contributed to a significant growth rate of the pig sub-sector in the country, e.g. pork annual growth rates were 7.4 and 3.5 % in the decades 1980-1990 and 1990–2000, respectively, compared to other classes of livestock such as beef (4.7 and 1.4 %), poultry (4.3 and 5.5 %) and small ruminants (2.0 and 2.4 %) (FAO, 2005). In 2000 – 2005 smallholder pig production contributed about 92-96 % of total pork (13.2 to 16 metric tonnes) consumed in the country (FAOSTAT, 2006). These observations provide an opportunity for alleviating the anticipated future scarcity of meat in the country if appropriate improvement plans of the pig sub-sector will be developed and implemented efficiently.

Regardless of a potential role of the pig sub-sector in the livelihoods of rural resource poor and evident contribution to the national food chain and income, the sector has been subjected to constraints, which threaten its sustainability. Porcine cysticercosis (PC) disease has emerged as a serious constraint affecting both pig industry and public health in Tanzania (Phiri *et al.*, 2003; Lekule and Kyvsgaard, 2003; Ngowi, 2004, 2005; Boa, 2005). Various studies from East and Southern Africa (Phiri *et al.*, 2003), Western and Central Africa (Zoli *et al.*, 2003), Asia sub-region (Rajshekhar *et al.*, 2003), and Latin America (Pawlowski *et al.*, 2005a) have consistently indicated positive relationships between poor pig production and marketing systems with PC problems. Problems associated with PC are found most often in rural areas in developing countries with poor hygiene where pigs are allowed to roam freely and eat human faeces (Pawlowski 2002; Phiri *et al.*, 2003; Murrel, 2005).

Limited studies in Tanzania indicate alarmingly high PC prevalence (Nsengwa, 1995; Boa *et al.*, 1995; Ngowi *et al.*, 2004; Boa, 2005; Komba, 2008). This disease has emerged as a serious public health problem affecting both pigs and human, hence causing significant constraints to nutrition and economic wellbeing especially for resource poor farming communities. Moreover, available literature show that the most pig producing areas dominated by smallholder pig keepers such as Southern Highlands of Tanzania (SHT) (Iringa, Mbeya, Ruvuma and Rukwa regions) with about 62 % of pig national herd and some parts of Northern Highlands (NH) (Arusha, Manyara and Kilimanjaro regions) with about 13 % of national herd are also among the PC endemic areas (Boa *et al.*, 1995; Ngowi *et al.*, 2004; Boa, 2005; URT, 2006; Komba, 2008).

Cysticercosis is an important parasitic zoonosis, affecting human and pigs caused by infection with the larval (metacestode) stage of the tapeworm *Taenia solium*. Cysticercosis due to *T. solium* is most prevalent in the rural communities of developing countries. For example, Perry *et al.* (2002) listed PC among devastating diseases facing the world's poor, ranking among the ten disease conditions that have the greatest impact on pig productivity and marketing as well as public health. *T. solium* forms cysts (cysticerci) in pig muscles and certain organs that diminish the value of pig carcasses which results in significant economic losses to individual farmers and the pork meat industry in endemic areas. Studies done on pig prices in Tanzania, (Ngowi, 2005) and Rwanda (Zoli *et al.,* 2003) showed price discounting rate of 60 and 50 %, respectively, for pigs infected with PC. Humans can also harbour the cystic stage in their tissues, causing cysticercosis or, if there is neurological involvement, neurocysticercosis which can eventually lead to epilepsy and death in humans (Medina *et al*., 1990; Garcia *et al*., 2002). Humans can thus act as both final host, harbouring adult egg-laying tapeworms in the small intestine, and intermediate host with the cysticerci in other locations. According to Pawlowski *et al.* (2005b), approximately 2.5 million people worldwide carry the adult *T. solium* tapeworm and not less than 20 million people are infected with *T. solium* cysticerci.

In Tanzania, the increasing trend of pig production and consumption has consistently developed pig and pork supply systems into longer market chains, which have consequently broadened the accessibility and availability of pork in most parts of country (URT, 2006). Parallel to this trend, consumer awareness and demand for meat quality attributes are also increasing (Caswell *et al*., 1998; Ngowi, 2005). The demand for improved meat safety attributed to an ever-increasing knowledge of meat-borne diseases is observed across the globe including Tanzania (Caswell *et al.*, 1998; Steinfeld, 2003; Boa, 2003). More importantly, unlike other food quality attributes, meat safety restrictions particularly PC is posing a unique challenge to smallholder pig marketing due to its direct and noticeable impact on economic losses to smallholder pig keepers, pig traders and general public health (Miranda, 2005; Pawlowski *et al.,* 2005a; Ngowi, 2005). In this context, PC has become a barrier to local, regional, and international trading of pigs and pork. Smallholder pig keepers have become the most vulnerable group along the pig production and marketing chain; vulnerable to income loss when their pigs' assets are lost due to PC and further vulnerable when their lives are prone to *T. solium* taeniosis and cysticercosis.

Despite the serious consequences of PC on public health and vibrant limitations it poses in improving the livelihoods of smallholder farming communities especially pig keepers, there are no adequate, and sustainable control measures established so far. However, theoretically the disease has been declared eradicable (Schantz *et al.*, 1993).

The need for improving sustainable pig production, consumption, and public health in Tanzania is inevitable. However, baseline information on the smallholder pig production and marketing systems in the country, which is the key basis for improvement, is inadequate. Furthermore, there is no information on market behaviour and limitations posed by PC along pig marketing chains, including information on risk factors enhancing transmission of PC in prevailing pig marketing systems.

Given this background, there is clearly a need to examine existing production and marketing systems and their relationship to PC in order to achieve sustainable improvements. This study is therefore aimed at establishing basic information on smallholder pig production and marketing systems and their influence on PC transmission. The outputs of the study will be an important catalyst in assisting the formulation of decision supporting systems for improving smallholder pig production, marketing, public health, and sustainable control of PC in Tanzania, and other countries with similar environment.

1.2 Objectives of the Study

1.2.1 Main objective

To establish baseline information on smallholder pig production and marketing in Tanzania, aimed at assisting the formulation of decision supporting systems for improvement as well as appropriate and sustainable control of PC

1.2.2 Specific objectives

i. To characterize smallholder pig production systems

ii. To identify and characterize smallholder pig marketing systems

iii. To evaluate risk factors and behaviours enhancing transmission of PC in smallholder pig production and marketing systems

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Livestock Production Systems

2.1.1 Definition and descriptions of livestock production systems

Livestock production system is the reflection of interactions of different elements in the production environment such as financial, geographical, agro-ecology and climatic environment (Macmillan and Kirton, 1997). Different scholars have consistently articulated a more or less similar perception to definition and description of a production system. For example Conway (1986) defined a system as “an assemblage of elements contained within a boundary such that the elements have strong functional relationship with each other but limited, weak, or non-existent relationships with elements in other assemblages.” On the other hand, Smith and Harrison, (1978) argued that “the systems analysis can be viewed as the consolidation of component knowledge obtained through science's traditional analytical approach in order to gain understanding of complete interactive systems”. Similarly, and specific to livestock production, Sossidou, (2003) defined livestock production systems as “an agricultural system that consist of a group of inter-related components and include series of practices planned, designed and installed to achieve wise use of natural resources”. According to Steinfeld *et al.* (2006), livestock production across the world is carried out under varying environment, techniques, socio-economic circumstances, and efficiency using diverse livestock species and resources. Within this wide variety of livestock production, there are certain patterns that can be categorized into various production systems. Livestock production systems have evolved over time in response to a number of interactive forces such as population growth, technological change, developments in markets and infrastructure and policy environment (Rao and Birthat, 2008). Moreover, variations across regions, livestock species, climatic and farming systems, external factors and production objectives, have lead to a range of classification of livestock production systems across the world (Devendra *et al.*, 2005).

Production systems have been also described based on regions and location settings reflecting different sets of horizons, such as broad spectrum focusing on a global perspective (Sere and Steinfeld, 1996; Thornton *et al.,* 2002), medium with continent or region perspective (Nestel, 1984; ILRI, 1995; Steinfeld *et al.*, 2006) and small and specific focusing on nation and/or parts of nation and explicit type of livestock (Nzigu *et al.*, 2002; Lemke *et al.*, 2002, 2007; Wabacha *et al.*, 2004; Khan and Usmani, 2005; Deka *et al.*, 2007; Deka and Thorpe, 2008). Moreover, due to variability of types of livestock kept and their practices in the diverse geographical and climatic environments, type of livestock and/or their interaction with other form of production enterprise (especially crops) have been used to describe production systems commonly known as mixed crop-livestock systems (Wilson., 1995; Rao and Birthal, 2008; Sulc and Tracy, 2007; Franzluebbers, 2007).

2.1.2 Livestock production systems in Africa

Various studies have been done to characterise livestock production systems in Africa (ILRI, 1995; Sere and Steinfeld, 1996; Thornton *et al.*, 2002; Nzingu *et al.*, 2003; Wabacha *et al.*, 2004; Ajala *et al.*, 2007). Different description domains were used by different authors to characterise certain livestock production systems in Africa. Most of production systems include land utilization in relation to crops and/or livestock production (particularly ruminant livestock), level of technology and intensity of management to describe different systems categories (ILRI, 1995; FAO, 2001;

Steinfeld *et al.*, 2006). For example, ILRI, (1995) described livestock production systems in Africa based on intensity of management and socio-economic factors. Notably, three main production systems were described, namely:

- Subsistence-oriented production systems whereby land and labour are the principal factors of production, mainly dependent on the weather and household production variables. Thus, they are less motivated to adopt new technologies being risk averse.
- Semi-subsistence production systems whereby the household produces significant amount of produce for household requirement and surplus for marketing, and
- Commercial or specialized production systems whereby money transaction and level of specialization are eminent and production levels are highly responsive to market signals and external inputs and services.

On the other hand, Sere and Steinfeld, (1996), classified livestock production systems that have been widely used globally and in Africa in particular based on sources of feed (Dry matter) fed to animals. Similarly, Thornton *et al.* (2002) relied on world livestock production systems described by Sere and Steinfeld (1996) to further classify East Africa livestock production systems based on type of crops, level of technology and intensity of management to differentiate between different systems categories.

2.2 Pig Production in Africa

2.2.1 Origin and evolution of pig keeping in Africa

Among the major domesticated livestock species in Africa, pigs have been relatively little researched compared to other livestock such as cattle, sheep, and goats. According to Blench (2000), the history of the domestication of pigs in Africa is highly controversial. Nevertheless, the domestication of pigs is presumed to have been carried out in Anatolia, and according to earliest archaeological studies the domestication is dated back to 7000 BC (Estein and Rechard, 1984, cited by Blench, 2000). Domestication of pigs in the ancient Near East and Egypt was alleged to have taken place from the end of the fifth millennium BC, thereafter, widespread from Egypt along North Africa and Nile (Blench, 2000). Whether they spread any further into Sub-Saharan Africa is still in doubt, however, Murdock (1959) cited by Blench (2000) considered that evidence for cultural embedding made it likely that there were old populations of pigs in various parts of the continent, but has yet to be confirmed archaeologically (Blench and Dendo, 2006). However, it appears that the bush pig (*Potamochoerus porcus*) and warthog (*Phacochoerus aethiopicus*) are the only truly indigenous members of the *Suidae* in Sub-Saharan Africa (Holness *et al.*, 2005). Moreover, it has been reported that domestic pig was used as major source of food for the Neolithic population of Tangier, Morocco between 4000 and 1000 BC (Gilman 1975).

The evolution of pig keeping in Africa from ancient time is not well documented, however, few reports showed substantial importation of pigs to Africa from other parts of the world, particularly from Europe and Asia (Holness, 1974; Blench and Dendo, 2006). For example, in North Africa there was considerable importation of pigs of

Mediterranean breeds from the earliest periods of European trade (Blench, 2000). In East and Southern Africa, pigs are alleged to have been introduced by Europeans (Holness 1974; Holness *et al.*, 2005). It is also reported that the Portuguese brought pigs to Eastern Africa coast in 16th century via Goa, therein, diffused inland along the Mozambique coast (Holness, 1974). This trend resulted into current pig distribution in Africa (Fig. 1). It has also contributed significantly to extensive diversity between the breeds and/or ecotypes of pigs in Africa including size, colour, and shape.

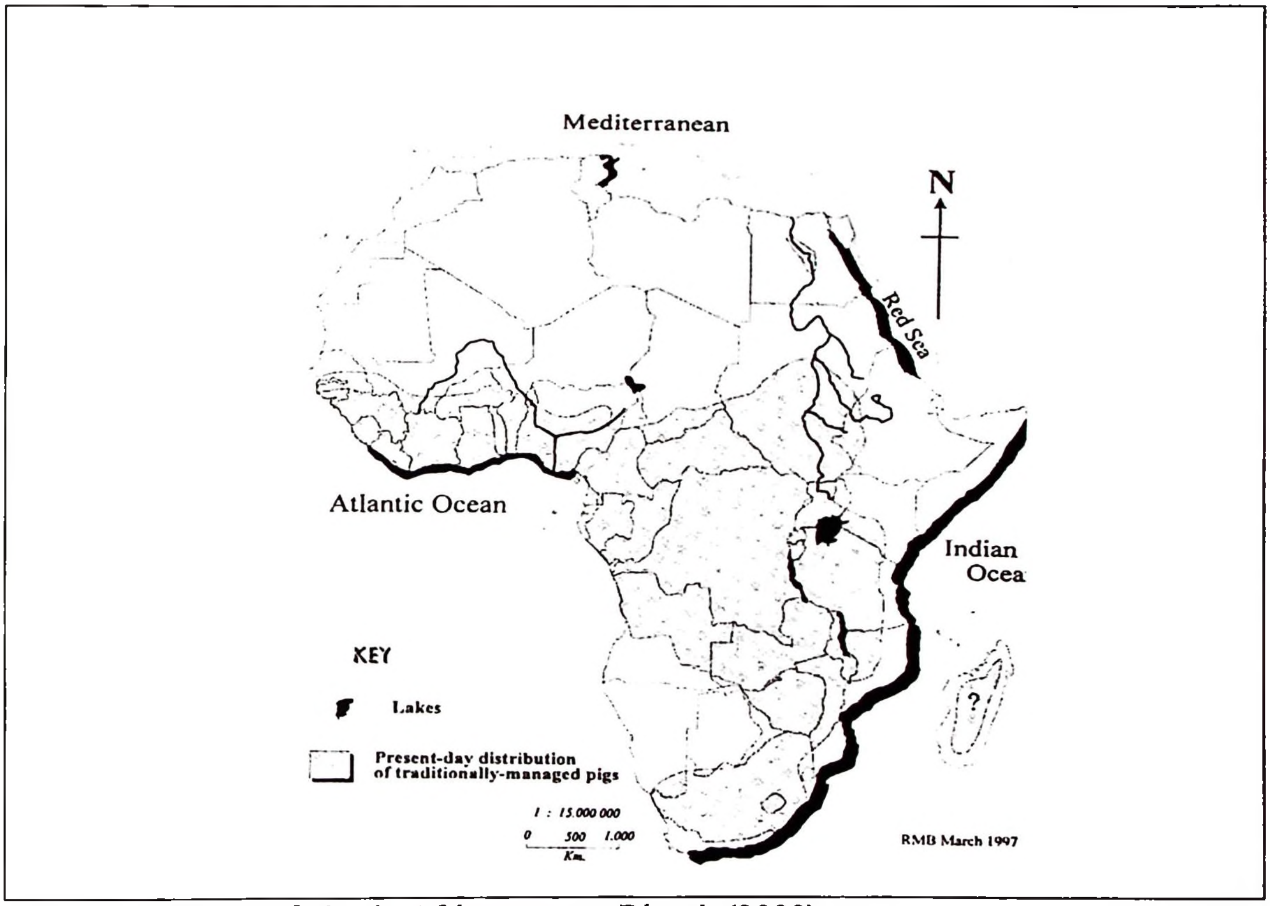

Figure 1: History of pigs in Africa, source: Blench (2000)

For example, pigs in Africa varied from the relatively small to medium size (e.g. Ashanti Dwarf in Ghana, and the Bakosi in Cameroon), to the larger (e.g. Windsnyer-type in Zimbabwe), which are longer in the leg with razor-backed, and the Kolbroektype in South Africa, which are shorter and fat, with a dished face (Mason and Maule, 1960, cited by Holness *et al.*, 2005).

2.2.2 Evolution of pig production systems in Africa

Pig production systems in Africa changed as evolution of pig keeping progressed. According to Merckx (1956), cited by Blench, 2000), the earlier system of pig production was semi-feral, whereby; pigs were mainly left to find their own feeds and in rare cases kept attached to inhabited units with prepared feeds. Production system changed as it was influenced by introduction of pigs from other parts of the world, where, pigs were more attached to inhabited units. Nevertheless, due to diverse nature of African agro-ecology, farming systems and socio-economic factors pig production system progressed differently in diverse locations (Holness *et al.*, 2005). In current situation, pigs are kept under, semi-confinement to confinement production systems, particularly in urban and peri-urban areas (Blench, 2000; Nsoso *et al.*, 2006; Campbell *et al.*, 2006). However, in the main parts of rural areas pigs are still kept under different traditional keeping systems as influenced by agro-ecology, farming systems and socio-economic factors (Blench, 2000; Kimbi *et al.*, 2003; Lyimo, 2003; Campbell *et al.*, 2006).

Blench (2000) and Campbell *et al.* (2006), classified four pig production systems in Africa, namely; scavenging, herding, semi-intensive, and intensive system (Table 1) with semi-intensive and free-range systems being the most dominant. Similarly, Holness *et al.* (2005), described free-range traditional systems as predominant in many parts of rural areas of developing world whereby pigs get most of their feeds freely around homesteads, kraals and vicinity areas, and sometimes supplemented with grain based feeds and kitchen leftovers. These traditional production systems contribute about 80% of pigs kept in East Africa (Lekule and Kyvsgaard, 2003), 75% in Zimbabwe, 70% in Botswana (Setschewaelo, 1992), 65% in Sahel countries (Chad, Niger, Mali, Guinea Bissau, Senegal) and 80% in Namibia (FAO, 1998).

Table 1: Pig production systems in Africa

Type of production system	Characteristics			
	Housing	Ownership	Feeding	Breeding
Scavenging	None	Often communal	None	Uncontrolled
Herded	None	Individual	Seasonal diets supplements	Uncontrolled
Semi-intensive	Semi-permanent constructed from local materials	Individual smallholder	Household waste and sometimes specially grown cassava	Uncontrolled or use of local stud boar
Intensive (modern)	Modern pens	Urban based entrepreneurs and businessmen	Agro-industrial by-products	Only selected stud boar

Source: Blench, (2000)

2.2.3 Pig production trend in Africa

Pig production has shown a considerable growing trend across different African regions, with exception of Northern Africa, which has experienced stagnation (Fig. 2). In the last two decades, East and West African regions have shown a higher growth rate in production compared to the South African region.

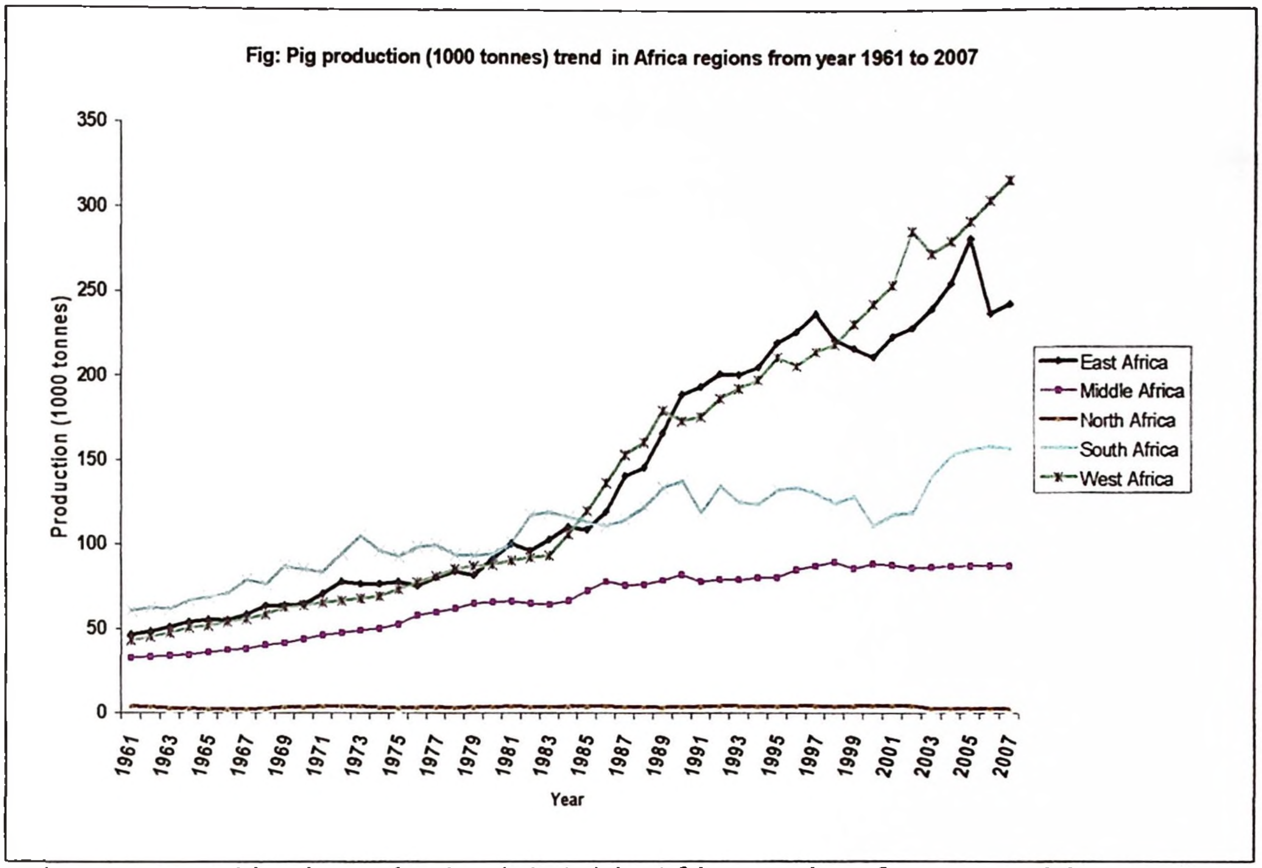

Figure 2: Trend in pig production (1000 t) in African regions from year 1961 to 2007 (source: FAOSTAT 2009)

2.3 Pig Production in Tanzania

2.3.1 Significance of smallholder pig production in Tanzania

Tanzania is an agrarian based country with about 80 % of labour force engaged in agriculture that contributes about 27 % of GDP (BPA, 2009). Over 80% of the people are in rural areas depending mainly on crops and livestock for their livelihood. Pig keeping is among the fast growing livestock enterprise in the country involving over 342 386 smallholder rural households (URT, 2006), representing about seven percent of the total number of smallholder farmers and 18 % of livestock keeping households in Tanzania.

According to URT (2006) the number of pigs kept by smallholders in Tanzania as of October 2003 were 973 972 and 535 for mainland and Zanzibar, respectively. Majority

(84 %) of smallholder farmers keep small herd size of one to four pigs with an average of two pigs per household, which, constitute about 50 % of national herd (Table 2). A few (1.2 %) smallholder farmers keep between 15 and 49 pig herd size (9 % of national herd) (Table 2).

Table 2: Households rearing pigs, number of pigs, and average number per household by herd size in Tanzania mainland

Herd size	Number of household	Percent	Number of pig	Percent	Average number per household
1-4	286 466	83.7	483 247	49.6	2
5-9	39 592	11.6	262 978	27.0	7
10-14	12 236	3.6	137 649	14.1	11
15-19	1 918	0.6	31 488	3.2	16
20-24	854	0.2	17 834	1.8	21
25-29	366	0.1	9 560	1.0	26
30-39	672	0.2	20 458	2.1	30
40 - 49	188	0.1	8 238	0.8	44
50 - 99	39	0.0	2 525	0.3	65
Total	342 331	100	973 972	100	3

Source: URT (2006)

Notably, Tanzania pig production data from various sources have shown some inconsistency particularly for pig population data, for example, FAO, and FAOSTAT pig population data (i.e. FAO, 2005 and FAOSTAT, 2009) versus data obtained from Tanzania Bureau of Statistics (e.g. URT, 2006). For examples Tanzania Bureau of Statistic data in Table 2 (URT, 2006) and FAO data in Table 3 (FAO, 2005)

2.3.2 Trend of smallholder pig production in Tanzania

Pig production trend in Tanzania have shown a high growth rate in terms of number and production (Table 3 and Fig. 3) in the last two decades compared to other main types of livestock (FAO, 2005; URT, 2006; FAOSTAT, 2009). According to URT, (2006) smallholder pig population, especially in mainland increased considerably from 434 638 to 973 972 (125 %) in 1995 and 2003 respectively. During the period between 1995 and 1999, smallholder pig population growth rate was considerably higher (17 % per annum) whereby the pig population increased from 434 638 to 821 696 compared to 1999 to 2003 period with annual growth rate of four percent. Similar growth trend was reported by FAO (2005) and FAOSTAT (2009). Tanzania pig production trend however, compared favourably with the neighbouring Kenya than Uganda as the pig production trend of Uganda experienced a drastic positive increase from 1987 onwards (Fig. 4) (FAOSTAT, 2009).

Table 3: Tanzania livestock population (x 1000) and annual growth rates for the periods between 1980 and 2000.

Species	Year				Annual growth rate (%)	
	1980	1990	2000	2002	1980- 1990	1990 - 2000
Cattle	12 578	13 047	16 713	17 367	0.4	2.5
Sheep and goats	9 437	12 083	15 390	15 839	2.5	2.4
Pigs	160	320	450	458	7.2	3.5
Poultry	18 100	21 048	29 048	30 320	1.8	3.0
Total LUs[1]	7 445	8 013	10 276	10 662	0.7	2.5

[1] LU: Livestock unit; conversion factors: cattle (0.50), sheep and goats (0.10), pigs (0.20), and poultry (0.01). Source: FAO (2005)

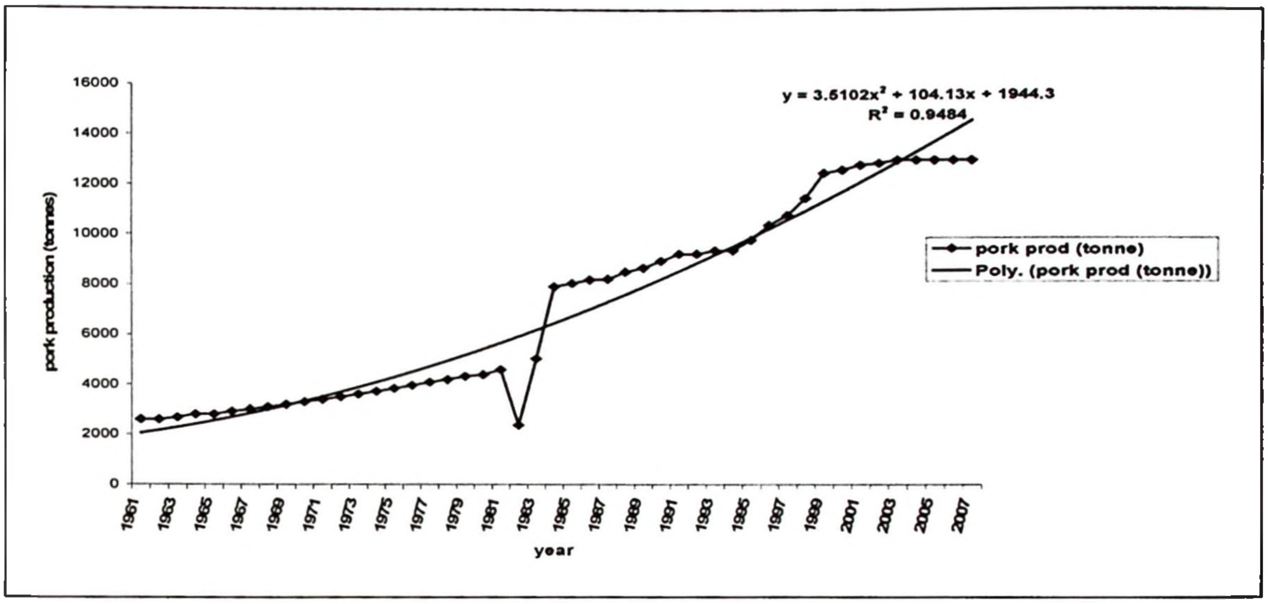

Figure 3: Trend in Tanzania pork production (tonne) from 1961 to 2002

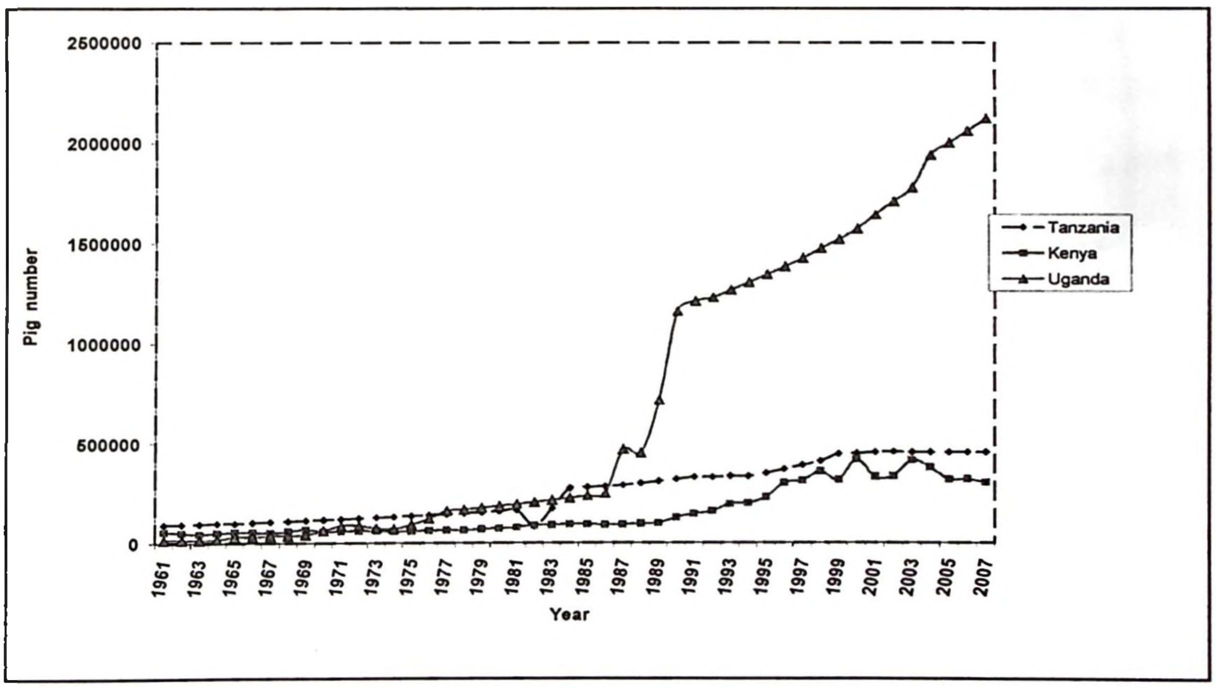

Figure 4: Comparative trend for pig population in East African countries (Tanzania, Kenya, and Uganda) for the period between 1961 and 2007 (source: calculated from FAOSTAT (2009)

2.3.3 Smallholder pig production in Southern Highlands of Tanzania

Most pigs in Tanzania are kept in high altitude areas where human population density is high and the land is of high agricultural potential (Lekule, 1995). Therefore, about 61 % of the pigs in the country are found in the Southern Highlands of Tanzania (SHT) regions (Mbeya, Iringa, Rukwa and Ruvuma) and 13 % in Northern Highlands (NH) (Kilimanjaro and Arusha) (Table 4) (URT, 2006). Pig keeping activities in SHT involved about 210 721 smallholder households (about 61.5 % of nation smallholder households keeping pigs) with about 594 731 pig numbers (about 61 % of national herd) (Table 4) (URT, 2006).

Among the famous pig keeping regions in the country, Mbeya is the leading with about 23.3 % of national pig herd and 23.0 % of smallholder households keeping pigs. It contains also higher pig density (number per square km of total land) of about 3.8 compared to their close counterparts Iringa (3.2), and Ruvuma (2.1) regions (URT, 2006). The study by Mwakasendo *et al.* (2006) in the SHT showed the profitability, simplicity, feed availability, and market accessibility as important factors, which motivated pig keeping in the area. Previous studies in Mbulu district, Northern Tanzania, revealed that pigs and local chickens were the only livestock species women allowed by their husbands to sell at any time and control the income (Ngowi *et al.*, 1999; Ngowi, 2005). Similarly, a study by Kimbi *et al.* (2004) in Rungwe and Mbozi districts, SHT also demonstrated that the family and women owned 57 % and 38 % of pig enterprises, respectively, while, men owned only 5%. The engagement of these community groups in pig sub-sector offers positive prospects for the contribution of sub-sector into poverty alleviation in resource poor rural areas.

Table 4: Households rearing pigs and pig population in Tanzania regions during October, 2003.

Region	State of smallholder household rearing pigs			
	Households rearing pigs (number)	Households rearing pigs (%)	Number of pigs	Average number of pigs per household
Mbeya	78 724	23.0	227 036	23.3
Iringa	67 150	19.6	180 904	18.6
Ruvuma	52 746	15.4	134 951	13.9
Kilimanjaro	32 844	9.6	116 877	12.0
Rukwa	12 101	3.5	51 840	5.3
Kagera	27 252	8.0	47 508	4.9
Morogoro	17 887	5.2	44 986	4.6
Dodoma	14 859	4.3	43 835	4.5
Manyara	16 210	4.7	41 236	4.2
Kigoma	5 024	1.5	23 698	2.4
Dar es Salaam	703	0.2	12 993	1.3
Arusha	3 154	0.9	7 958	0.8
Singida	2 288	0.7	6 375	0.7
Mtwara	3 355	1.0	6 293	0.6
Tabora	2 614	0.8	6 286	0.6
Tanga	2 601	0.8	6 281	0.6
Lindi	1 407	0.4	4 956	0.5
Pwani	353	0.1	3 673	0.4
Shinyanga	656	0.2	3 266	0.3
Mara	328	0.1	2 409	0.2
Mwanza	76	0.0	610	0.1
Total Mainland	342 331	100.0	973 971	99.9
Total Zanzibar	54	0.0	535	0.1
Whole country	342 386	100.0	974 506	100.0

Source: URT (2006)

Pig production in Mbeya region is among the important agricultural enterprises involving about 78 724 smallholder households (21 % of the total agricultural household in the region) with about 227 036 pigs in total (Table 5). Majority (81 %) of pig keepers in the area keep less than five pigs per household which represent 47 % of total regional pig population, whereas, 15 % of households keep between 5 to 9 pigs per household (representing 34 % of the total regional pig population) (URT, 2006). According to the national sample census of Agriculture (URT, 2006) report, Mbozi is the leading district in Mbeya region with 26 % of the regional pig population, followed by Rungwe district (21%), Chunya (15%), Mbeya Rural (15 %), Kyela (14%), Mbarali (5 %), Ileje (3 %), and Mbeya Urban (1%) (Table 6).

Table 5: Number of households rearing pigs, number of pigs, and mean number per household according to herd size in Mbeya Region by 1st October 2003

Herd size	Number of household	Percent	Number of pigs	Percent	Mean number per household
1 – 4	63 893	81	106 653	47	2
5 – 9	11 436	15	77 783	34	7
10 – 14	2 693	3	30 976	14	12
15 – 19	335	0	5 678	3	17
20 – 24	350	0	5 467	2	16
25 – 29	17	0	479	0	28
Total	78 724	100	227 036	100	3

Source: URT (2006)

Pig production trend in Mbeya region as forecasted using population growth trend generally has shown a considerable positive magnitude to certain periods. For example, the overall annual growth rate of the pig population for the eight years period from 1995 to 2003 was 6.9 % whereby the population grew from 133 274 to 227 036 pigs (URT, 2006).

Table 6: Number of households rearing pigs and number of pigs per household in Districts of Mbeya region.

District	Households rearing pigs	Number of pigs	Average number per household
Mbozi	17 965	57 898	3
Rungwe	24 018	47 019	2
Chunya	7 144	33 814	5
Mbeya Rural	10 846	33 535	3
Kyela	11 132	32 292	3
Mbarali	2 594	11 798	5
Ileje	4 460	7 516	2
Mbeya Urban	565	3 164	6
Total	78 724	227 036	3

Source: URT, (2006)

2.4 Overview of Pig Marketing in Tanzania

Despite being small-scale system constituting individual smallholder farmers, pig production is primarily market-oriented activity with about 95 to 99 % of pigs been disposed through selling (URT, 2006; Mwakasendo *et al.*, 2006). The income from pig sales meets essential household and farming expenses and provides some financial independence to the women in the family. Studies of smallholder pig keepers in Tanzania have shown that the main reason for keeping pigs is income generation through selling of pigs (Ngowi, 2005; Mwakasendo *et al.*, 2006). Due to increased preference of pork in both villages and urban areas in the country, pig production, marketing, and consumption have consistently increased whereby products supply systems are developing into longer market chains to involve various market participants. Regardless of its low consumption compared to other sources of meat in the country, pork showed a promising growth trend particularly in the last two and half decades (FAO, 2005; FAOSTAT, 2009). Moreover, the observed trend of pork consumption in the country has been closely associated with the increase in pig marketing in the country. The coverage of pig and pork marketing in the country has widened to almost every region including Zanzibar, however, variation does exist between and within regions. Number of pigs traded varies across regions in the country, with relatively higher extent in regions of high pig population (Table 7). Due to their prolificacy and high growth rate, the percent of pigs traded to pigs reared (Table 7) is generally high across the regions, denoting the high market turnover rate of pig enterprise, which might be associated with promising pig off-take rates of smallholder pig enterprises.

Almost all pork produced in the country is marketed for domestic consumption (FAO, 2005; FAOSTAT, 2009). Moreover, the import dependency for pork is higher than export reflecting unfulfilled demand of either quantity or quality from local pork supply (Table 9) (FAO, 2005). The importation of pork showed a declining trend during the period between 1961 and 1990, however, the trend started to grow again from 1991 onwards (Table 8), most likely market liberalization policy contributed to the latter. Similar trends were also observed for value of pork imported versus exported and net trade value of pork (Table 8) (FAO, 2005). The FAO data on import-export of pork showed that the export of pork as percent of production in the country is smaller compared to imports as percent of consumption (0.3% versus 2.1%) (Table 9) (FAO, 2005). These trends demonstrated the gap, which still exists in addressing quantitative domestic demand of pork, and above all, ability to address the quality and quantity for export.

Table 7: Number of pigs sold/traded during 2002/03 agriculture year

Region	Number of pigs sold/traded	Percent of pig traded to pig reared
Kilimanjaro	102 804	88
Ruvuma	73 833	54.7
Iringa	62 471	34.5
Mbeya	60 304	26.6
Manyara	56 211	136.3
Rukwa	28 314	54.6
Morogoro	20 561	46
Dodoma	8 970	21
Kagera	6 904	14.5
Arusha	1 617	169
Kigoma	6 254	26.4
Tanga	3 866	62
Dar es Salaam	3 993	31
Mtwara	3 744	59.5
Singida	2 879	45.2
Lindi	2 554	51.5
Tabora	2 166	34.5
Mwanza	381	62.5
Mara	70	2.9
Pwani	53	1
Shinyanga	44	1.3
Total mainland	447 992	46.0

Source: URT (2006)

Table 8: Amount (tonne) and value (US $ 1000) of pork imported and exported in Tanzania during 1961 to 2006.

Quantity and value of pork imported and exported	Year					Total
	1961-1970	1971-1980	1981-1990	1991-2000	2001-2006	
Average quantity of pork (t)						
imported	126.9	40.6	-	12.2	46.7	45.2
exported	1.3	3.1	-	9.7	11.3	4.5
Net trade (quantity)	-125.6	-37.5	-	-2.5	-35.3	-40.6
Value of pork (US $ 1000)						
imported	122.3	29.8	-	26	112.5	53.4
exported	1.5	5.4	-	7.5	24.7	6.3
Net trade (value)	-120.8	-24.4	-	-18.5	-87.8	-47.0

Source: calculated values based on FAOSTAT (2009)

Table 9: Export –import dependency of pork compared to other livestock meat products

Meat product	Year			
	1980	1990	2000	2002
Export as percent of production				
Total meat	0.13	1.58	0.10	0.03
Pork	0.00	0.0	0.42	0.34
Poultry	0.00	0.00	0.42	0.00
Sheep and goats	0.00	0.00	0.18	0.13
Beef and buffalo	0.18	2.20	0.01	0.00
Imports as percent of consumption				
Total meat	0.07	0.04	0.18	0.21
Pork	0.29	0.09	2.76	2.13
Poultry	0.00	0.00	0.18	0.51
Sheep and goats	0.00	0.00	0.03	0.11
Beef and buffalo	0.09	0.05	0.07	0.04

Source: FAO (2005)

2.5 Porcine Cysticercosis

2.5.1 Aetiology and taxonomy

Porcine cysticercosis is an important parasitic zoonosis affecting pigs caused by infection with the cestode, *T. solium* (Flisser *et al.*, 2005). The term 'cysticercosis,' denotes tissue infection with the larval or cysticercus (metacestode) stage of the cestode (Pawlowski, 2002). It was during the middle of 19^{th} century when it was established that cysticercosis in human was caused by the ingestion of *T. solium* eggs.

T. solium is belongs to the genus Taenia (Pawlowski, 2002). The genus *Taenia* has about 20 species, however, the important ones are *T. solium* (pork tapeworm) and *T. saginata* (beef tapeworm; man definitive host and cattle intermediate host) which have been reported to be potential health hazards to human (Pawlowski, 2002; Flisser *et al.*, 2005). Moreover, contrary to *T. saginata*, *T. solium* has a greater importance in public health because it is lesser in specificity for its intermediate host, as it can also infect humans and give rise to human cysticercosis. The latter often leads to neurocysticercosis (NCC), a major cause of epilepsy associated with considerable morbidity and mortality (Hidalgo, 2007). *T. solium* cysticercosis contributes to a considerable pig production losses in endemic areas due to downgrading/ condemnation of pig carcasses (Phiri *et al.*, 2003; Carabin *et al.*, 2005).

2.5.2 Life cycle and mode of transmission

Taenia solium (pork tapeworm) has a two-host life cycle, with humans as the only definitive host carrying the adult tapeworm in the small intestine, a condition known as taeniosis (*s.* taeniasis) and pigs as the intermediate host harbouring the larval cysts (cysticerci) in muscles and certain organs (Soulsby, 1982). Other natural intermediate hosts of the tapeworm include bush pigs, dogs, cats, rats, and monkeys (Gracey, 1986). Humans occasionally become intermediate host after ingesting eggs of the tapeworm, a disease known as human cysticercosis (Soulsby, 1982; Pawlowski, 2002).

A human is infected by ingesting raw or undercooked pork with cysticerci that contain viable larvae or from eggs in faecal contaminated food or water (Fig. 5) (Murrell, 2005). Upon reaching the human intestine, the cysticercus loses its bladder wall and develops into a mature, egg-producing worm. The tapeworm has a head (scolex), which attaches to host's intestinal mucosa (Naquira, 1999; Pawlowski, 2002). Its short neck is the portion with the highest biosynthetic activity associated to the formation of the immature proglottids (segments) (Pawlowski, 2002). It contains germinative cells from which new segments grow up to form a long and segmented strobilus (Naquira, 1999). The strobila (chain of segments) can measure up to 4 m in length with a total of 800 to 1 000 proglottids (segments). The gravid proglottids contain from 30 000 to 50 000 eggs, which detach from the strobila in groups of five or six and are expelled with faeces (Naquira, 1999; Pawlowski, 2002). *T. solium* tapeworms shed up to 300 000 eggs daily, each containing an embryo with six hooks (Naquira, 1999). When eggs are released from the definitive host, most are fully embryonated and infective to a suitable host, but others may be at different stages of maturation (Murrell, 2005). Eggs that are shed into faeces may serve as a source of infection (or autoinfection) to people in closer contact with carriers; however, most are disseminated to the environment (Harrison and Sewell, 1991).

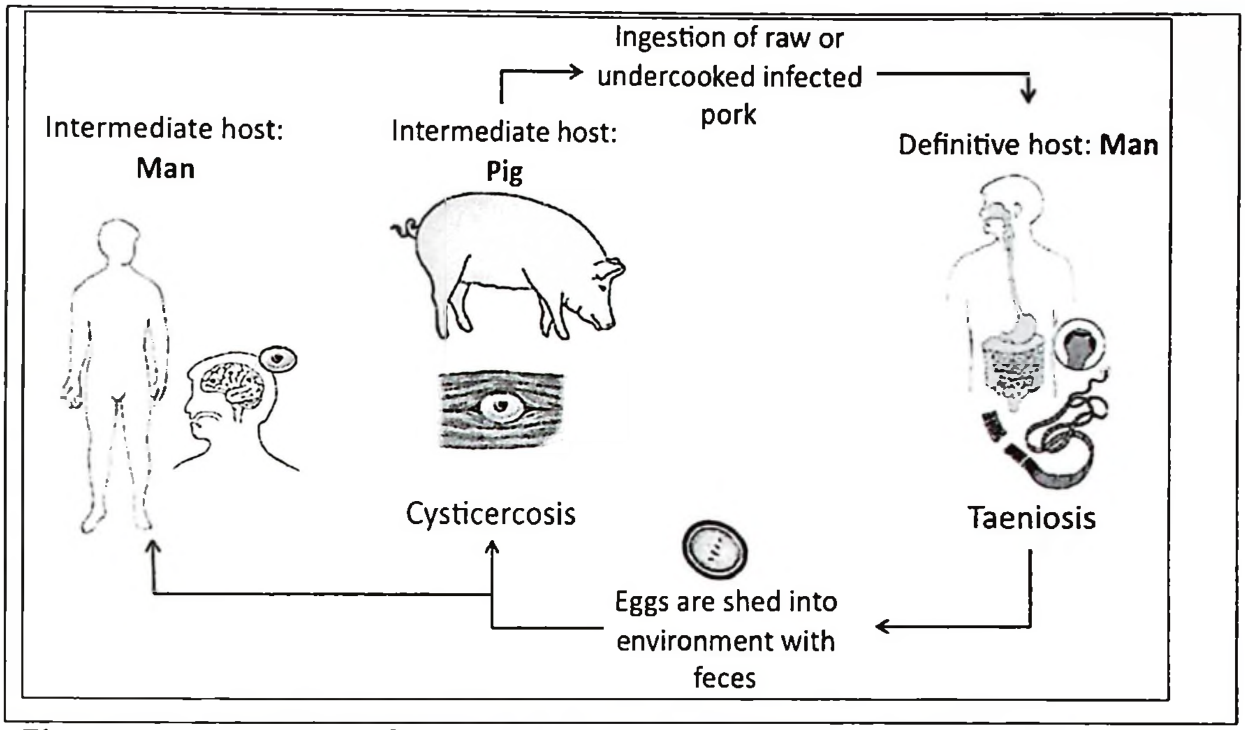

Figure 5: Taenia solium life cycle (source: Deckers, 2009)

Number of disposal agents such as wind and water are believed to aid the disposal of *T. solium* eggs, however there is little experimental evidence supporting the assumption (Murrell, 2005). *T. solium* eggs are assumed to be reasonably defiant to external environmental conditions and common disinfectants (Hidalgo, 2007).

A pig is infected when ingesting food, water, or human faeces containing viable *T. solium* eggs or proglottids (Harrison and Sewell, 1991). After the eggs have been ingested, the six-hooked larvae hatch. The matured larvae are liberated and activated in the gut by the aid of luminal factors such as bile salts and enzymes (Pawlowski, 2002; Flisser *et al.,* 2005). Two hours after liberation, the larvae adhere to sub-mucosa blood and/or lymphatic vessels and migrate to internal organs and tissues (Pawlowski, 2002). In pigs, most common sites for cysticerci are the cardiac, skeletal, diaphragmatic, and lingual musculature as well as brain. In humans, the common predilection sites are the musculature, subcutaneous tissue, and brain (Schantz *et al.*, 1998; White, 2000). The post-larvae development proceeds within the tissue, and the larva is differentiated into a fluid filled bladder (ovoid vesicle), having a group of cells that differentiate further into invaginated scolex (Pawlowski, 2002). Larvae require at least 12 weeks to developing into fully infective cysticerci (Harrison and Sewell, 1991).

2.5.3 Epidemiology

2.5.3.1 Geographical distribution of PC

A *T. solium* population at any time involves three distinct subpopulations; adult tapeworms in the definitive host (man, possibly dogs), larval stages in intermediate hosts (pigs and to a small extent man), and eggs in the environment. Therefore, due to interdependency of these subpopulations it has been recommended to consider all subpopulations when assessing the epidemiology of *T. solium* (Flisser *et al.,* 2005).

T. solium is cosmopolitan in distribution and is highly endemic in Africa, Latin America, and Asia, particularly in countries associated with pork-eating, poor sanitation and places where intimate contact between humans and pigs is common (Mafojane *et al.*, 2003; Flisser *et al.,* 2005). Cysticercosis is associated with poverty, areas where people eat undercooked or raw pork and traditional-extensive pig husbandry is dominant (Zoli *et al.,* 2003; Sikasuge *et al.*, 2007). Moreover, globalisation, which has encouraged immigration from and travels in endemic zones, has increased the number of tapeworm carriers in industrialized countries (Schantz *et al.*, 1992; Shandera *et al.,* 2002). Availability of information and variation of *T. solium* cysticercosis/taeniosis prevalence across the world has led into four defined areas (Fig. 6) (WHO, 2003).

T. solium cysticercosis is one of the most important zoonotic diseases in the world known to pose serious public health threats and economic losses. The annual incidence of taeniosis across the globe is estimated to vary between 10 and 50 million people (Crompton, 1999), and more than 50 million pigs are infected with cysticerci of *T. solium* (Bern *et al.*, 1999; Eddi *et al.*, 2003). Furthermore, approximately 400,000 patients are having disease symptoms from NCC, which causes about 50,000 deaths annually (Craig *et al.*, 1996; Bern *et al.*, 1999; Crompton 1999). Nevertheless, the geographical and socio-economic variations across the regions of the world have imposed disparity in different domains integrating pigs and human in relation to *T. solium* cysticercosis/taeniosis such as; the levels of sanitation, pig husbandry systems, pig/pork marketing systems and finally pig slaughter, inspection and pork eating behaviours. Consequently, the prevalence of PC varies markedly across the world, regions, and countries and even within countries.

Africa

The trend of increased pig production in sub-Saharan Africa, mainly in smallholder pig production systems, has also contributed to the considerable increase of *T. soliun* taeniosis and cysticercosis in the continent (Lekule *et al.*, 2003; Phiri *et al.*, 2003: Zoli *et al.*, 2003; Mafojane *et al.*, 2003).

T. solium infections affect most of Africa, except for Muslim regions where pig keeping and pork utilization is at very low levels for religious reasons (Mafojane, *et al.*, 2003; Phiri *et al.*, 2003; Zoli *et al.*, 2003;). *T. solium* cysticercosis and taeniosis have been reported in several countries in different regions of Africa. For example; in the West Africa region *T. solium* taeniosis/cysticercosis have been reported in Nigeria

(Dada, 1980; Onah and Chiegina, 1995; Weka and Ikeh, 2009), Ghana (Permin *et al.*, 1999), Ivory coast (Mishra and N'Depo 1978, cited by Zoli *et al.*, 2003), Togo (Balogou *et al.*, 2000), and Benin (Houinato *et al.*, 1998) (Table 10).

In Central Africa region cysticercosis/taeniosis have been reported in Chad (Assana *et al.*, 2001), Cameroon (Pouedet *et al.*, 2002, Shey-Njila *et al.*, 2003, Thomas, 2004), Congo (Pandey and Mbemba, 1976) and Rwanda and Burundi (Newel *et al.*, 1997; Zoli *et al.*, 2003). DR Congo, Rwanda, and Burundi have been recognized as hyper-endemic for cysticercosis with prevalence figures exceeding 25 % in pigs in several regions and many case reports of human cysticercosis (Brandt, 1997; Zoli *et al.*, 2003).

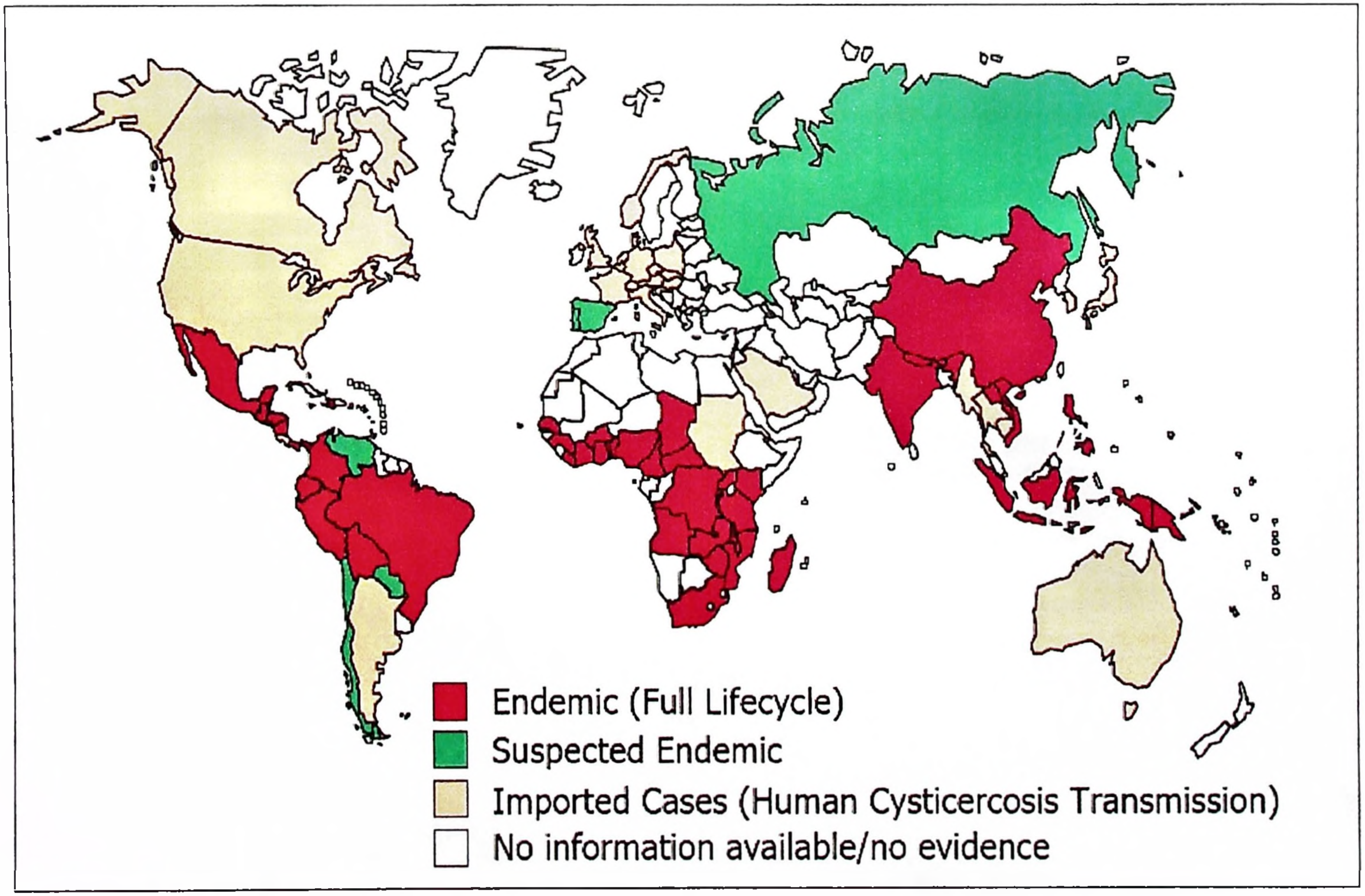

Figure 6: Global distribution of *Taenia solium* taeniosis/cysticercosis (Source: http://www.who.int)

Table 10: Prevalence of PC in some West and Central African countries

Country	Prevalence (%)	Number of pigs surveyed	Diagnostic test[a]	Area surveyed	Reference
Burkina Faso	0.57	NA[b]	R	Nation	Coulibaly and Yameogo, (2000)
Nigeria	1.8 – 18.4	-	R	Slaughter houses	Dada, (1980)
	20.5	2358	P	Nsukka area of Enugu State	Onah and Chiegina, (1995)
	46.0	63	S	Middle-Belt State	Weka and Ikeh, (2009)
Ghana	11.7	60	P	Upper East Region	Permin *et al.* (1999)
Cameroon	10.9	707	L,S	West Cameroon	Pouedet *et al.* (2002)
	4.4	383	L	NW Cameroon	Shey-Njila *et al.*
	27.7	271	S	,,	(2003)

[a] P = post mortem, L = lingual examination, S = serological, R = retrospective meat inspection data, [b]NA = not available

In South Africa region *T. solium* cysticercosis and taeniosis has been reported in Zimbabwe, Zambia, South Africa, Mozambique, and Madagascar (Table 11) (Mafojane *et al.*, 2003; Phiri *et al.*, 2003; Sikasuge *et al.*, 2008).

In Zambia, considerable work has been carried out in recent 10 years (Phiri *et al.*, 2002, 2003; Sikasuge *et al.*, 2007, 2008). Most pigs in Zambia are raised by smallholder farmers mainly under extensive production system, thus, contributing to high prevalence of *T. solium* cysticercosis and taeniosis (Phiri *et al.*, 2003). For example, a survey involving pig abattoirs in Lusaka reported prevalence ranging between 10.9 and 20.6 % in pigs using lingual and meat inspection respectively (Phiri *et al.*, 2002). On-farm surveys showed that 8.2 and 5.2 % of pigs from Southern and Eastern provinces, respectively, were positive for cysticercosis by tongue palpation, while, Ag-ELISA showed prevalence of 20.8 and 9.3% for the same pigs and location, respectively (Phiri *et al.*, 2002). Similar trend was also reported by Sikasuge *et al.*, (2008) in Eastern, Southern Provinces with prevalence in pigs ranging between 7.0-20.6 % and 16.0-56.6 % for lingual, and Ag ELISA, respectively.

Pig keeping in South Africa is largely characterised by intensive, commercial production systems which are highly dominating in urban and peri-urban areas (Heinz and MacNab, 1965; Krecek, *et al.*, 2008). Nevertheless, in rural areas extensive pig production is still dominant and thus contributes to prevalence of *T. solium* cysticercosis and taeniosis in both rural areas and urban areas (Mafojane *et al.*, 2003; Phiri *et al.*, 2003). In an early nationwide survey involving 67 slaughterhouses and more than 100 000 pigs in South Africa, Viljoen (1937) found prevalence of PC varying between 0.5 and 25.1 %. A recent community based survey of pigs owned by smallholder farmers in Eastern Cape Province (Krecek *et al.*, 2008) reported a PC prevalence of 11.9, and 33.3 % (n = 261 pigs) for lingual examination and enzyme-linked immuno-electrotransfer blot (EITB) assay, respectively. In this study, using Bayesian estimate, the true PC prevalence was 64.4 %

In Mozambique, pig keeping is dominated by smallholder farmers practicing extensive production, which is characterised by high prevalence's of *T. solium* taeniosis and cysticercosis (Vilhena *et al.*, 1999; Afonso *et al.*, 2001; Mafojane *et al.*, 2003; Gule, 2008). Abattoir records indicate that PC is present in all provinces of the country (Mafojane *et al.*, 2003). The seroprevalence findings, reported by Afonso *et al.* (2001), showed the presence of PC in 11 districts of Tete Province with prevalence ranging between 6.5 and 33.3 %. Gule (2008) reported PC prevalence of 5.4 % out of 205 carcasses going into meat inspection chain in Angonia district in Tete province.

In Zimbabwe pig production is mainly emanating from both intensive commercial farms and smallholder production systems. Smallholder systems is dominant in poor rural areas where pigs are sold at informal markets and sanitation is poor (Phiri *et al.*, 2003). In smallholder communities, the prevalence of PC has increased from 2.7 to 28.6 % during the period of 1995 and 2002 and is emerging as an important problem (Mukaratirwa, 2002 cited by Mafojane *et al.*, 2003). In the past, during 1960s to 1970s the reported prevalence of PC in Zimbabwe was low, 0.03, and 4.3 % (Table 11) (Robinson, 1978, cited by Phiri *et al.*, 2003).

Table 11: Results of prevalence studies on PC conducted in Southern Africa countries

Country	PC prevalence (%)	Number of pigs surveyed	Type examination/ test[a]	Area surveyed	Reference
Zambia	20.6 – 56.6	1316	S, P	Lusaka	Phiri *et al.* (2001)
	8.2 – 20.8	249	L, S	Eastern and Southern Provinces	Phiri *et al.* (2002)
	15.2 – 28.3	772	L, S	Southern Province: Gwembe & Monze Districts	Sikasuge, *et al.* (2008)
	7.0 – 16.9	769	L, S	Eastern Province: Petauke and Katete Districts	
	7.3 – 30.0	150	L,S	Western Province: Mongu District	
Zimbabwe	0.03 – 4.3	1000000	P	National	Robinson (1978), cited by Phiri *et al.* (2003)
	2.7 - 28.6	99525	P	Western Region	Matega *et al.* (2002)
Mozambique	6.5 – 33.3	387	S	Tete province	Afonso *et al.* (2001)
South Africa	0.5 – 25.1	> 100000	P	National	Viljoen, (1937)
	0 – 9.1	28242	P	National	Heinz and MacNab (1965)
	11.9 – 64.5	261	L,S,B	Eastern Cape Province	Krecek, *et al.* (2008)

[a] P = post mortem, L = lingual examination, S = serological, B = bayesian estimate of true prevalence

In East Africa region, *T. solium* taeniosis and cysticercosis have been reported to include all the countries in the region; Tanzania, Kenya and Uganda (Table 12) (Boa *et al.*, 1995; 2001; Phiri *et al.*, 2003; Ngowi *et al.*, 1999, 2004; Githigia *et al.*, 2005; Waiswa *et al.*, 2009; Kagira *et al.*, 2010). A recent community based survey by Waiswa *et al.* (2009) in Kaliro and Kamuli districts which involved 513 pigs, showed a seroprevalence of PC of 8.5 %. On the other hand, much higher prevalence rates were reported from a district rural survey done in northern part of Uganda, in which 34-45 % of pigs slaughtered in selected villages were infected, thus, verifying the high burden of disease in rural environments (Anyanzo, 1999, cited by Phiri *et al.*, 2003). Similarly, post-mortem survey of carcasses for pigs from districts of central region of Uganda and rural northern district of Lira showed zero prevalence for pigs from central and 33.7 % for pigs from rural northern of Lira with overall of 9.4 % (Kisakye and Masaba, 2002).

In Kenya *T. solium* cysticercosis and taeniosis were not considered to be endemic during the previous decades, maybe due to the decision by government to ban free-range pig keeping and/or inadequate prevalence studies and reports from village areas. However, from last decade smallholder pig keeping is becoming popular particularly in rural areas such as southwest Kenya (Mafojane *et al.*, 2003; Phiri *et al.*, 2003; Githigia *et al.*, 2005). In these areas extensive production system is common practice accompanied by informal pig and pork marketing and slaughter practices which predispose for cysticercosis and taeniosis (Githigia *et al.*, 2005; Kagira *et al.*, 2009).

In Tanzania T. *solium* taeniosis and cysticercosis has been reported as emerging and increasing problem in different smallholder pig population systems in the country (Table 12) (Boa *et al.*, 1995; Nsengwa, 1995; Ngowi, 1999; Boa *et al.*, 2006; Komba, 2008; Mkupasi, 2008). PC was initially reported in mid 1980s when pigs from Mbulu district in Northern Highlands of Tanzania which were exported to Kenya were found to be heavily infected with the disease at slaughter (Nsengwa, 1995). Based on retrospective study of slaughter slab records Nsengwa (1995) reported an increasing PC prevalence from 0.41 to 4.88 % in Mbulu district from 1985 to 1989, respectively. In the follow-up study in 1993 which involved post-mortem survey of pigs slaughtered at different slaughter slabs in Arusha, Moshi and Mbulu in Northern Highlands, Boa *et al.* (1995) found that 4.5 to 37.7 % of pigs were infected, mainly from Mbulu district. In a community based survey involving lingual examination of pigs in villages of Mbulu district, Ngowi *et al.* (2004) reported an overall district prevalence of 17.4 % (n = 770), with prevalence of individual villages (n = 21) ranging from 3.2 to 46.7 %. A similar community based study involving lingual examination of pigs in Chunya, Iringa-rural and Ruvuma (Songea and Mbinga) districts in the Southern Highlands of Tanzania, reported an overall prevalence of 7.6 (n = 722), 8.4 (n = 808) and 16.9 % (n = 302), respectively (Boa *et al.,* 2006). A recent community based study in Mbozi and Mbeya rural districts, reported an overall prevalence of PC of 11.7 and 32 % based on lingual examination and Antigen-ELISA, respectively (Komba, 2008). In Mbeya Rural district, the prevalence was 6.0 and 30.7% by lingual examination and Antigen-ELISA tests, respectively.

Table 12: Results of prevalence studies on PC conducted in East Africa countries

Country	Prevalence (%)	Number of pigs surveyed	Type examination/ test[a]	Area surveyed	Reference
Kenya	10.0 – 14.0	407	L	Busia and South Nyanza Districts	Githigia *et al.* 2002
Tanzania	0.04 – 4.9	45794	P	Mbulu District	Nsengwa (1995)
	4.5 – 37.7	83	P	Northern highlands	Boa *et al.* (1995)
	3.2 – 46.7	770	L	Mbulu District	Ngowi (2004)
	0 – 26.9	1789	L	Chunya and Iringa districts	Boa *et al.* (2006)
	5 – 60 %	600	S	Mbozi and Mbeya rural districts	Komba (2008)
	5.9 %	731	P	Dar es Salaam city	Mkupasi (2008)
Uganda	33.7 – 44.5	600	P	Moyo District	Anyanzo (1999), cited by Phiri *et al.*, (2003)
	0 – 33.7[C]	297	P	Central and Northern Districts	Kisakye and Masaba (2002)
	8.5	480	S	Kamuli and Kaliro Districts	Waiswa *et al.* (2009)

[a] P = post mortem, L = lingual examination, S = serological (Ag-ELISA), B = bayesian estimate of true prevalence

2.5.4 Risk factors for porcine cysticercosis transmission

According to Murrell (2005), risk factor assessment for *T. solium* taeniosis and cysticercosis need to consider both extrinsic and intrinsic factors that influence the transmission of *T. solium* eggs and cysticercus stage. In this scenario, thorough understanding of *T. solium* transmission requires risk assessment of the acquisition of the adult tapeworm infection and the dispersal of the tapeworm's eggs from faeces to pig and human.

2.5.4.1 Transmission from humans to pigs

Various factors may enhance the transmission of *T. solium* eggs to pigs. Pig management systems and practices as they are interacting with feeding behaviour of pigs have been indicated as important factors influencing the infection pressure (Murrell, 2005). An extensive (e.g. free-range) production system of pigs has been shown by various studies in different geographical locations as an important risk factor for transmission of *T. solium* eggs to pigs. For example, Sikasuge *et al.* (2008) reported a significantly higher PC prevalence in the households practicing free-range system compared to those kept under semi-intensive system in Eastern, Southern and Western Provinces of Zambia. Likewise, risk assessment study done in Mbulu District – Northern part of Tanzania showed free-ranging pigs and lack of latrine in the households as important risk factors for disease transmission (Ngowi *et al.*, 2004). Similar observations have been reported in different geographical locations elsewhere in Africa: South Africa (Krecek *et al.*, 2008), Cameroon (Assana *et al.*, 2001; Pouedet *et al.*, 2002), Zimbabwe (Robinson, 1978 cited by Phiri *et al.*, 2003), Uganda (Waiswa *et al.*, 2009); Latin America (Sarti *et al.*, 1992; Sakai *et al.*, 2001) and in Asia (Juyal *et al.*, 2008). The qualification of free-range system as risk factor has however, revealed other underlying (confounding) factors such as presence and extent of use of latrines in the households. Studies in Africa have positively associated absence of latrines in the households and free-range system as important risk factors (Shey-Njila *et al.*, 2003; Ngowi *et al.*, 2004; Thomas, 2004; Sikasuge *et al.*, 2007; Krecek *et al.*, 2008). While, studies in Latin-America have shown the liberal feeding of faeces to pigs (such as, using of pigs to clean human faeces 'sanitary policemen', and use of human faeces as pig feed i.e. connecting pig pens to human latrines 'pig sty privies') was important risk factors for transmission of PC (Sarti *et al.*, 1992; Sakai *et al.*, 2001). Risk assessment study done in Cameroon showed that the free-ranged pigs with access to human faeces had considerably higher prevalence rate than confined pigs not fed human faeces (Assana *et al.*, 2001). Beyond the cultural setting, liberal feeding of faeces to pigs in resource poor communities is motivated by human faeces' characteristics of being rich in nutritive value, cheap and palatable to pigs, in spite of the fact that it represents a major risk factor for PC. However, in most parts of Africa feeding faeces to pigs is not a common cultural phenomenon.

Human tapeworm carriers were also shown by various studies as an important (necessary) risk factor facilitating the occurrence of both porcine and human cysticercosis particularly when personal hygiene is not observed (Garcia-Garcia *et al.*, 1999; Vazquez-Flores *et al.*, 2001; Zoli *et al.*, 2003; Lescano *et al.*, 2007). In a study to estimate PC risk gradient surrounding tapeworm carriers in Peru, Lescano *et al.* (2007, 2009) showed an exponential increase of seroprevalence and seroincidence rates of PC with decreasing distance to carriers. Pigs owned by tapeworm carriers had higher (four times) PC seroincidence compared to other pigs ($P < 0.005$). Similar findings have been reported in Peru (Lescano *et al.*, 2007; 2009), Mexico (Sarti *et al.*, 1992), and USA (Flisser, 2003). Tapeworm carriers host the adult tapeworm and disseminate infective *T. solium* eggs in their faeces, leading to a major risk factor to both pigs and human. Existing evidence suggests that, carriers can contaminate the environment beyond their households. Higher numbers of cysticercosis cases in human and pigs in households neighbouring *T. solium* carriers have been reported (Allan *et al.*, 2002; Lescano *et al.*, 2007, 2009)

2.5.4.2 Transmission from pigs to humans

The transmission of *T. solium* eggs from humans to pigs has been considered as the primary and essential link in the 'pig-man-pig cycle' (Murrell, 2005). It have been also stipulated that behaviour of humans contribute greatly in facilitating disease transmission from pigs to human being. Pig and pork marketing systems especially in rural environments have been reported as important risk factors in disease transmission (Phiri *et al.*, 2002, 2003; Krecek *et al.*, 2008). However, there is very limited quantitative information on these risk factors, maybe because infected pigs are normally sold at clandestine channels and no efforts have been made to study these. In most PC endemic regions particularly in rural areas, a large proportion of pigs are marketed through informal channels, thus increasing the potential risk of passing infected pork to consumers (CWGP, 1993; Murrell, 2005; Krecek *et al.*, 2008). In a study done in Peru, CWGP (1993) demonstrated that about 65 % of pork consumed in the country is obtained through informal channels associated with poor slaughter supervision and inspection. Similar observations have been also reported in South Africa (Krecek *et al.*, 2008), Zambia (Sikasuge *et al.*, 2007) and Cameroon, (Thomas, 2004). Informal systems of marketing pigs have been closely linked with poor and unsupervised pig slaughter and inspection, and thus, commission the latter to be the important risk factors.

Unsupervised slaughters and poor pork inspection contribute considerably to the consumption of cysticerci infected pork (CWGP, 1993; Phiri *et al.*, 2003; Zoli *et al.*, 2003). Studies in Zambia (Phiri *et al.*, 2002; Sikasuge *et al.*, 2007), South Africa (Krecek *et al.*, 2008), and Peru (CWGP, 1993) have clearly demonstrated lack of satisfactory pig slaughtering and lack of pork inspection as important risk factors for disease transmission. Some studies assessing PC prevalence, for example, Robinson (1978) cited by Phiri *et al.* (2003) in Zimbabwe, Heinz and MacNab (1965) in South Africa, have used abattoir/slaughter slab post-mortem data to estimate PC prevalence in pigs. It is however important to realize the limitations of such studies. Data were not representative of the true situation because large proportions of pigs, and certainly PC pigs, are traded and slaughtered at clandestine channels outside the abattoirs. This has been exemplified in rural areas of Mexico (Aluja, 1982). Consequently, pig and pork marketing systems, slaughtering, and inspection practices all need to be considered in control.

Pawlowski *et al.* (2005a) suggested a switch from total reliance on meat inspection as a basic control strategy to active diagnosis and treatment of human taeniasis, protection of pigs against infection, promotion of health education and improved surveillance preparing chemotherapeutic and/or sanitary interventions as improved options for controlling the disease in endemic areas.

Inadequate knowledge of people on *T. solium* taeniosis and cysticercosis facilitates the transmission of human taeniosis as well as human and PC. It has been anticipated that people with inadequate knowledge on *T. solium* taeniosis and cysticercosis infection are likely to expose themselves or their pigs to sources of *T. solium* infections, such as contaminated foodstuffs or water. Studies done in Tanzania (Ngowi *et al.*, 2004), Honduras (Sanchez *et al.*, 1998) and Zambia (Phiri *et al.*, 2002) demonstrate the lack or inadequate knowledge as an important risk factor for transmission. Furthermore, cultural preference of eating raw or improperly cooked pork, have been also indicated as important risk factor for disease transmission from pigs to man (Pawlowski *et al.*, 2005a).

2.5.4.2 Person to person transmission

Human to human transmission occurs when one ingests *T. solium* eggs in contaminated food or water (Soulsby, 1982; Pawlowski, 2002). A person with intestinal taeniosis may also be auto-infected which involve the ingestion of eggs from faeces by contaminated hands, 'faecal-oral infection' (Pawlowski, 2002). Negligence of hygienic principles such as washing hands after defecation and before consuming meals is the principal reasons for external autoinfection. In this context, various risk factors have been reported to enhance human to human transmission, including: low economic status (Sanchez *et al.*, 1998), low level of household sanitation and low personal hygiene standards (Sarti *et al.*, 1992; Sanchez *et al.*, 1998; Silva-Vergara *et al.*, 1998), history of passing proglottids by a member of a household or a member of the community in frequent contact with such a household (Garcia-Garcia *et al.*, 1999; Lescano *et al.*, 2007; Prasad *et al.*, 2009)

2.6 Conceptual Framework and Key Assumptions for Smallholder Pig Production and Marketing Systems

2.6.1 Conceptual framework overview

A conceptual framework as an analytical framework presents a guiding outline of the empirical inquiry of the most useful research domain on which analysis and limited resource should focus. This framework considers the fundamental way of life confronting smallholder pig production, marketing, and information needed to answer study objectives (Fig. 7). Smallholder pig keepers' decision making to adopt certain production/management system and consequent marketing options is influenced by several interacting factors. Therefore, decision and adoption constitute the reflection of an array of interacting variables, in space and time with consideration of returns among the evaluation criteria. According to Lynne *et al.* (1988; cited by Hella, 2003), "the evaluation of an outcome for a person is defined conceptually as the strength of his positive and negative outcome." Returns to production system are a stochastic/random variable and choosing between alternative production/management systems based on returns, constitute decision making under risk (Senkondo, 2000). Since the link between decisions made by smallholder pig keepers to ensure their survival is behavioural centred arising from interacting endogenous and exogenous factors, therefore, both positive (survival i.e. livelihood sustenance) and negative (diseases i.e. PC transmission) effects are among the outcomes emanating from adopting a certain production and/or marketing system. Therefore, this study considers smallholder pig production and marketing systems as an outcome from interactions among exogenous, endogenous, and inherent individual households' factors (Fig. 7). The framework conceptualization is also based on the philosophy of the general definitions of a system as defined by Conway (1986), and the specific definition of livestock production systems as defined by Sossidou, (2003). In this respect, research on smallholder production systems requires an understanding of the relationship between system components. Therefore, based on the conceptual framework of this study, the following suggestions have been considered as key assumptions underlying smallholder pig production and marketing systems in relation to PC transmission.

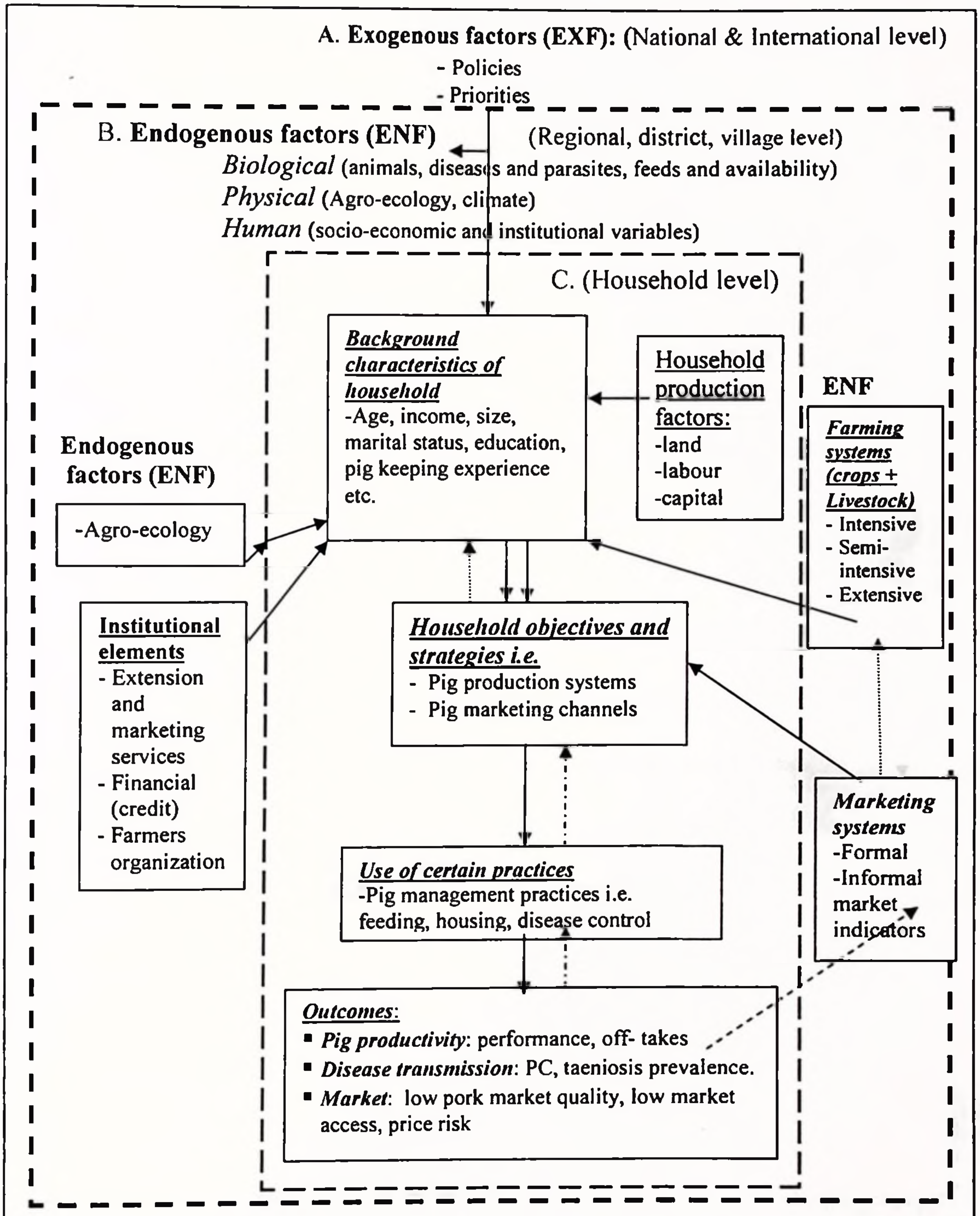

Figure 7: Conceptual framework describing some exogenous, endogenous, and inherent individual households' factors, which might influence adoption of different production, and marketing systems by smallholder pig keepers.

2.6.2 Assumptions

2.6.2.1 Assumptions pertaining smallholder pig production and marketing systems

i. Smallholder pig keepers are operating under specified types of production/management systems

ii. A production/management system adopted by household is the result of decision made to ensure rational use of available resource (i.e. land, labour, and capital) to produce output that supports the household

iii. Each production/management system has certain set of characteristics, which are influencing inputs-outputs relationship of the system.

iv. Each production/management system is made up of elements which relate and interact to influence production pattern (production characteristics) of the system

v. Smallholder pig production circumstances i.e. endogenous and exogenous factors influence the production decisions and pig performance characteristics

vi. Household characteristics such as age, sex, family size, education level, marital status, land size, wealth status, livestock holdings, etc. have the influence in decision making which affect type of production/management systems and practices to be used

vii. Human environment such as socio-economic and institutional elements (i.e. extension services, prevailing marketing systems) influence household objective settings on type of production/management systems to use which eventually result into different types and levels production, marketing and diseases prevalence especially PC and taeniosis.

viii. Infrastructural development (i.e. roads, markets, water, pig slaughter-houses) has influence on smallholder pig production and marketing systems

2.6.2.2 Assumption pertaining smallholder pig production and marketing system and PC transmission

i. Types of pig production/management systems used by smallholder pig keepers have varying influence on transmission of PC

ii. Types of pig marketing systems have the influence on type(s) of marketing channels used by different market participants

iii. Types of pig market channels used by different market participants have varying effects on transmission of PC

iv. Human environment such as socio-economic status, culture, aspects of hygiene (e.g. availability and use of latrines, access and use of water), and levels of awareness/knowledge of health aspects of cysticercosis influence transmission of PC

v. Pig slaughtering and inspection practices (e.g. slaughter facilities and quality of meat inspection) and consumption behaviour (eating and ways of cooking pork) influence transmission of PC.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

The study was conducted in Mbeya Region in the Southern Highlands of Tanzania with particular focus in Mbozi, Mbeya Rural and Mbeya Urban (City) districts. Mbeya region was purposively selected due to a large number of pigs (23.3 % of national herd) and smallholder households (23 % of national smallholder households) keeping pigs, as well as existing local descriptions of constraints to smallholder pig production and marketing (URT, 2006).

3.1.1 Description of Mbeya region

Mbeya region is located in the South Western corner of the Southern Highlands of Tanzania. It lies between Latitudes 7° and 9° 31′ S, and between Longitudes 32° and 35° E (URT, 1997a). Mbeya region lies at the altitude between 475 meter above see level (masl) at Lake Nyasa and 2981 masl at Rungwe Peak. Mbeya shares borders with countries of Zambia and Malawi to the immediate South; Rukwa Region to the West; Tabora and Singida Regions to the North; while Iringa Region lies to its East, with Tunduma and Kasumulu in Mbozi and Kyela districts, respectively, being the main entries and/or exits into neighbouring countries of Zambia and Malawi. The Region has an area of 63, 617 km^2 which is 6.4 % of the total area of Tanzania. Out of the regional total area, 57,000 (89.6 %) km^2 is arable land (URT, 1997a). The Region is divided into eight administrative districts namely Chunya, Ileje, Kyela, Mbarali, Mbozi, Mbeya Rural, Mbeya Municipal and Rungwe (Fig. 8). The districts are further divided into a total of 25 divisions, 135 wards, and 577 villages (URT, 1997a).

3.1.2 Description of study districts

3.1.2.1 Mbozi district

Mbozi district is located in the South Western corner of Mbeya Region (Fig. 8), between latitudes 8° and 9°12' S and longitudes 32° 7' 30" and 33° 2' 0" E (URT, 1997b). Mbozi is bordered by Ileje district in the South and Mbeya rural district in the East. To the North, Mbozi district extends to Lake Rukwa where it is bordered by Chunya district, whereas to the West it shares borders with Rukwa Region and the Republic of Zambia. Mbozi district is among the largest (third to Chunya and Mbarali districts) districts in Mbeya Region occupying 15 % of the region's total land area. It occupies a total area of 9679 km^2 whereof 79.2% (7666.4 km^2) is arable land, 9.7 % (937.4 km^2) is forest reserve, 8.1% (783.22 km^2) is settlement and other uses and the remaining 3 % is covered by water bodies (URT, 1997b). Administratively, Mbozi district is divided into six divisions, 26 wards, and 152 villages (URT, 1997b).

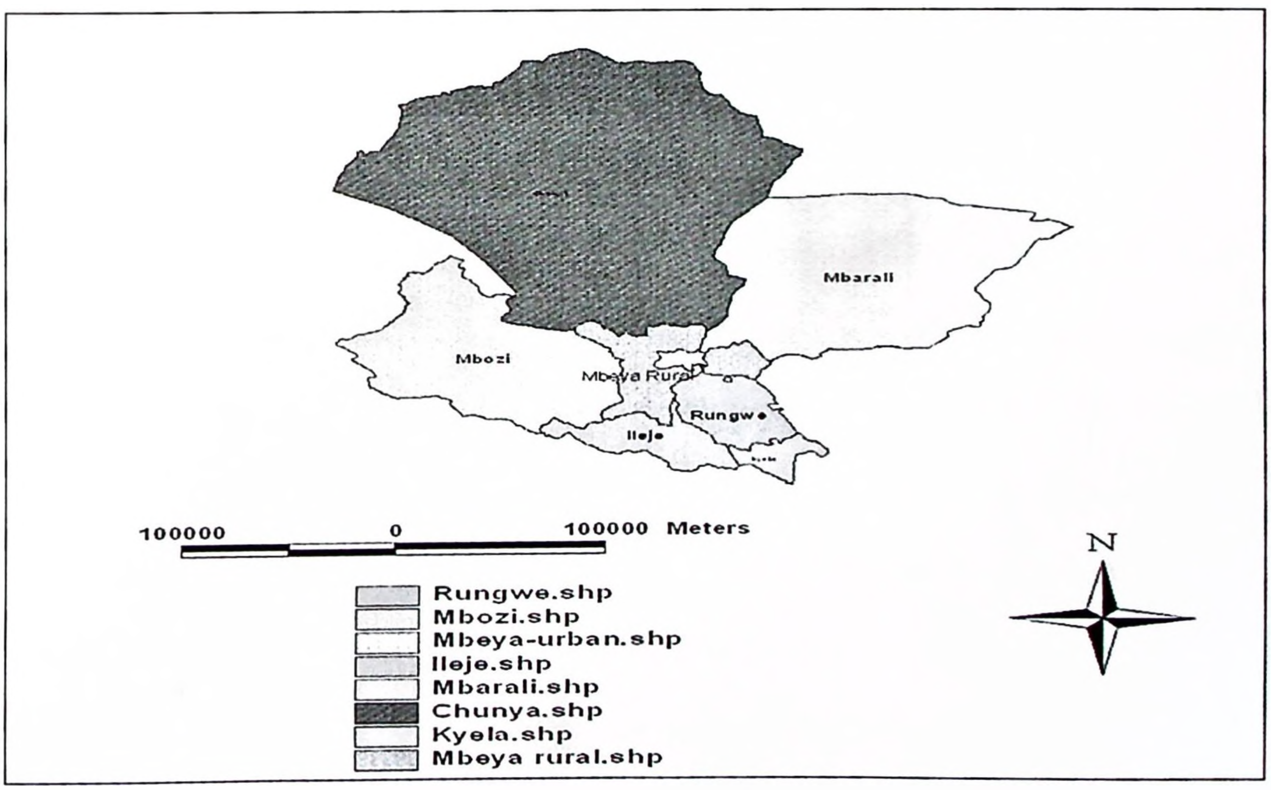

Figure 8: Mbeya region showing location of study districts among region districts

3.1.2.2 Mbeya rural district

Mbeya rural district lies between latitude 8° 38' and 9° 20' S and longitude 33° and 33° 52' E (URT, 1997c) (Fig. 8). Mbeya rural is the fourth largest district of Mbeya Region occupying a total area of 3093 km^2 (4.9 % of the region totals) (URT, 1997a). Mbeya rural is administratively divided into three divisions, 17 wards, and 126 villages (URT, 1997a).

3.1.2.3 Mbeya urban district

Mbeya urban (Mbeya city) is one of the eight districts of Mbeya region located in the centre of the Mbeya region (NBS, 2003). It lies between latitude 8° 50' and 8° 59' S and longitude 33° 21' and 33.35' E (URT, 1997a). It is bordered to the North East by Mbarali district, the remaining portion is surrounded by Mbeya rural district (Fig. 8). It occupies an area of 185 km^2 (0.3 % of region total area). The district is divided into 36 administrative wards among which 16 (44.4 %) wards have mixture of urban and rural setting, 6 (16.7 %) rural setting, and 14 (38.9 %) urban setting (URT, 1997a).

3.2 Main Study Focus, Research Phases and Study Designs

The main study involved two main components of smallholder pig sub-sector, specifically production and marketing components. The study design constituted five main research phases, that is: a local community survey using Participatory Rural Appraisal (PRA), a cross-sectional study focusing on pig keepers, a prevalence study for porcine cysticercosis (PC) focusing on pigs kept by smallholders, a longitudinal prospective study focusing on smallholder pig keepers and pig production, and a cross–sectional study focusing on pig traders. The general framework of the study was designed to utilize principles of multiple data source as suggested by Marsland *et al.*, (2005). The primary target domain for the former four studies was smallholder pig keepers' households and their pig production and marketing circumstances, while, the latter study was the pig traders and their pig marketing circumstances.

Preliminary study: reconnaissance survey and collection of secondary information

A reconnaissance survey was carried out in Mbeya region aimed at appraising pigs' production dynamics, streamlining study design, and targeting research domain. The study involved livestock and agricultural extension officers and key informants; the Regional Livestock Advisor, and the respective District Agriculture and Livestock Development Officers (DALDO's). The survey also overviewed the general information on pig population and distribution, agro-ecological zones, pig production and marketing setup, and some clues on PC prevalence in the area.

3.2.1 Study areas and research designs

3.2.1.1 Study 1: Participatory Rural Appraisal (PRA)

Study area

The PRA study was carried out in Mbeya rural and Mbozi districts (Fig. 9).

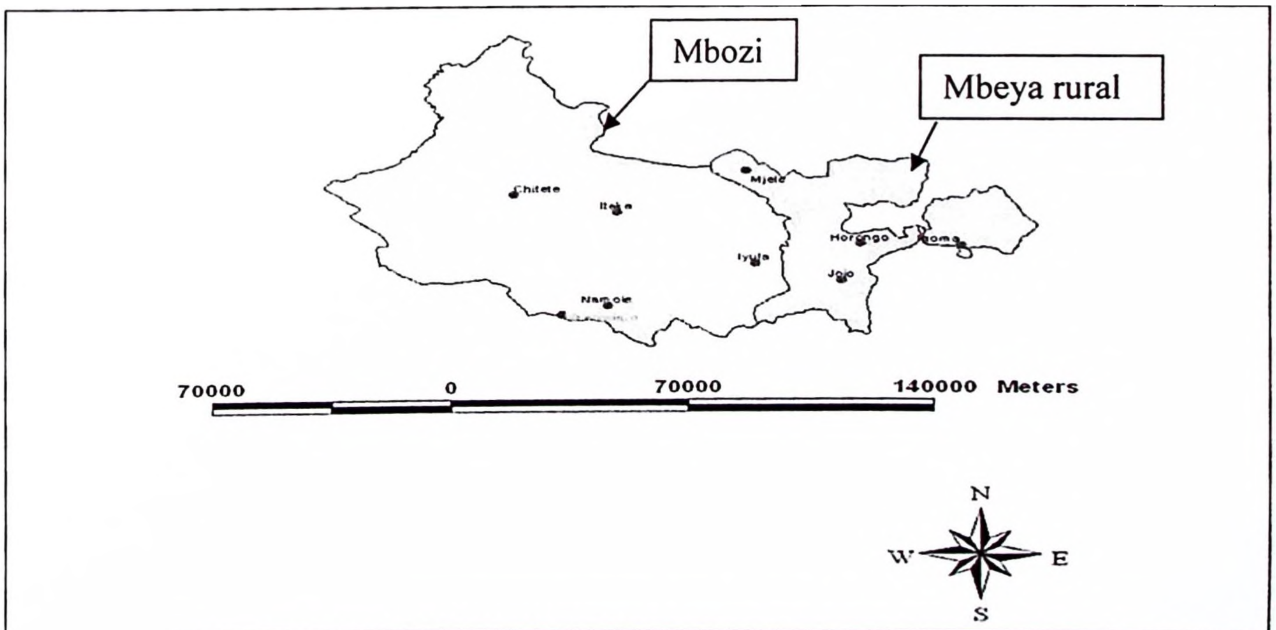

Figure 9: PRA study villages in Mbozi and Mbeya rural districts

Research design and sampling procedure

Topical PRA survey design was employed to collect exploratory and explanatory information for diagnosing and characterizing the smallholder pig production environment in the context of farming systems approach (Matata *et al.*, 2001; Kirway *et al.*, 2003). Nine villages; four villages from Mbeya rural and five from Mbozi districts were selected. The villages were selected from the 30 villages sampled for cross-sectional study (study 2); representing 30 % of villages participating in the cross sectional study two (section 3.2.1.2). Villages were randomly selected from agro-ecological zones (AEZ) list for each district (Table 13) (Mussei *et al.*, 1999; Kirway *et al.*, 2003). The villages selected for PRA were visited before the actual PRA meetings for the purpose of general appraisal and acclimatisation, discussion with village leaders and key informants on the purpose of study, setting appointment and agreeing on specific places for the meetings and targeted people.

Village PRA interview meetings

Both PRA group meetings and key informants interviews were carried out in targeted villages. Group meetings involved different age groups and gender (Table 13). Key informants interviews involved village leaders and extension officers (if any) working in the same villages. Key informants in this context were essentially the knowledgeable individual(s) who were in the position of providing information, ideas, and insights on aspects related to the study. The study used different PRA tools and techniques such as direct observations, semi-structured interviews (group interviews, key informants interviews), ranking (pair wise matrix) and trends (historical profile of pig production and PC). A facilitator well trained and experienced in farming systems approaches led the PRA exercise. Interviews were guided by á well designed checklist (Appendix 1). All interviews outputs were recorded using relevant recording materials such as flip charts and notebooks. All interviews were conveniently done using Kiswahili.

Table 13: Profile of PRA study villages

District	Division	Ward	Village	Agro- Ecological Zone (AEZ)	Altitude (masl)	Total number of households	Number of pigs	PRA participants		
								Male	Female	Total
Mbeya rural	Usongwe	Mshewe	Mjele	7C: Rukwa-Songwe valley	980	303	210	21	13	34
	Usongwe	Igale	Horongo	1O: Mbeya stepped plain	1587	495	92	17	13	30
	Tembela	Ulenje	Igoma	1L: Mporoto – Umalila highlands	2373	1100	1200	15	11	26
	Isangati	Satilya	Jojo	1L: Mporoto – Umalila highlands	2035	801	290	26	15	41
Mbozi	Msangano	Chitete	Chitete	4F: Songwe-Msangano Itumba trough	966	575	309	14	2	16
	Ndalambo	Nkangamo	Nkangamo	4G: Tunduma – Ndalambo stretch	1666	422	785	3	17	20
	Igamba	Itaka	Itaka	1N: Mbozi plateau	1603	1164	209	28	14	42
	Ndalambo	Chiwezi	Namole	4H: Lyambalyamfipa escarpment	1356	408	400	17	12	29
	Iyula	Iyula	Iyula	1N: Mbozi plateau	1741	1451	302	20	14	34
Total						6719	3797	161	111	272

Data analyses

PRA data was analyzed manually for context and recurrent themes in the text whereby varying levels of inductive and deductive protocols were used (Saunders *et al.*, 2003). Two levels of analyses, on-site and off-site were adopted as proposed by Pretty *et al.*, (1995). On-site data analysis involved PRA tools especially direct listing, pair wise matrix ranking and historical profile. Off-site data analysis involved harmonization (clustering) of data between and within locations, relate the consistency and inconsistency of comments and the specificity of responses and drawing specific inferences.

PRA data was used to describe main and important economic activities performed by smallholder pig keepers, main livestock kept, and importance of pig keeping in their farming system and experience of PC in their pig-keeping environment.

3.2.1.1 Study 2: Cross-sectional survey of pig keeping households

Study area

A cross sectional survey study using structured questionnaire (Appendix 2) was carried out in Mbeya rural and Mbozi districts of Mbeya region (Fig. 10). The description of the districts is given in section 3.1.2

Study design and sampling procedure

A cross–sectional survey design using single visit multiple subject procedure was employed to collect data from smallholder pig keeper's households. The study was designed to collect data on pig production and marketing circumstances and prevalence of PC in pigs kept in the household at a single point in time in order to establish relationship between pig production, marketing, and PC prevalence.

Participating villages were randomly selected from the established sample frame for villages keeping pigs in each study district. Sample size for participating villages and households were selected based on Bartlett *et al.,* (2001) formula: $n_o = t^2 \cdot p \cdot q/d^2$, where; n_o is the required sample size per district, t is value for selected alpha level of 0.05, p is known or estimated variance (i.e. p is proportion of households keeping pigs) and q is 1 – p (proportion of non pig keepers households) and (d) is acceptable error. In this study, p was estimated at 11% (URT, 2006), t value was estimated at 1.96 (for sample size above 120), and d was assumed at 0.05. Thus, $n = (1.96)^2 \times 0.11 \times 0.89/(0.05)^2 = 150.43$. Based on the estimated sample size, 30 villages (15 villages per district) were randomly selected. In each selected village, 10 pig keepers' households were randomly selected for interview to give a total sample size of 300 households. In this study, a "household" is defined as the persons or members who are residing under one roof or under several roofs but, share the common source of food and answerable to the same head of household. On the other hand, a smallholder pig keeper was defined as "an individual pig keeper living in a rural area of the study district" (Ngowi, 2005). The established districts and villages sampling frame was used as baseline frame for study 1 and 3 in order to establish studies inter-linkage. Profile of study area and respondents is shown in Table 14

Table 14: Profile of study area and respondents in cross sectional study

Districts	Number of wards	Number of villages	Number of respondents	Gender of respondents		Gender of household head	
				Male	Female	Male	Female
Mbozi	12	15	151	99	52	131	20
Mbeya rural	9	15	149	92	57	125	24
Total	21	30	300	191	109	256	44

Estimation of sample size for pig to be examined for PC was based on Thrusfield (1995) formula; $n = Z^2 PQ/L^2$, where; n is the required sample size, Z is confidence level, P is known or estimated prevalence, Q is 1 – P and L is allowable error. Confidence level was assumed at 95% with allowable error (L) of 0.05. The PC prevalence was estimated at 11 % (Boa, 2005; Komba, 2008). Thus, $n = (1.96^2 \times 0.11 \times 0.89)/0.05^2 = 150$ pigs. The sample was multiplied by two for adjustment of multistage sampling design to give 300 pigs to be examined in each of two districts.

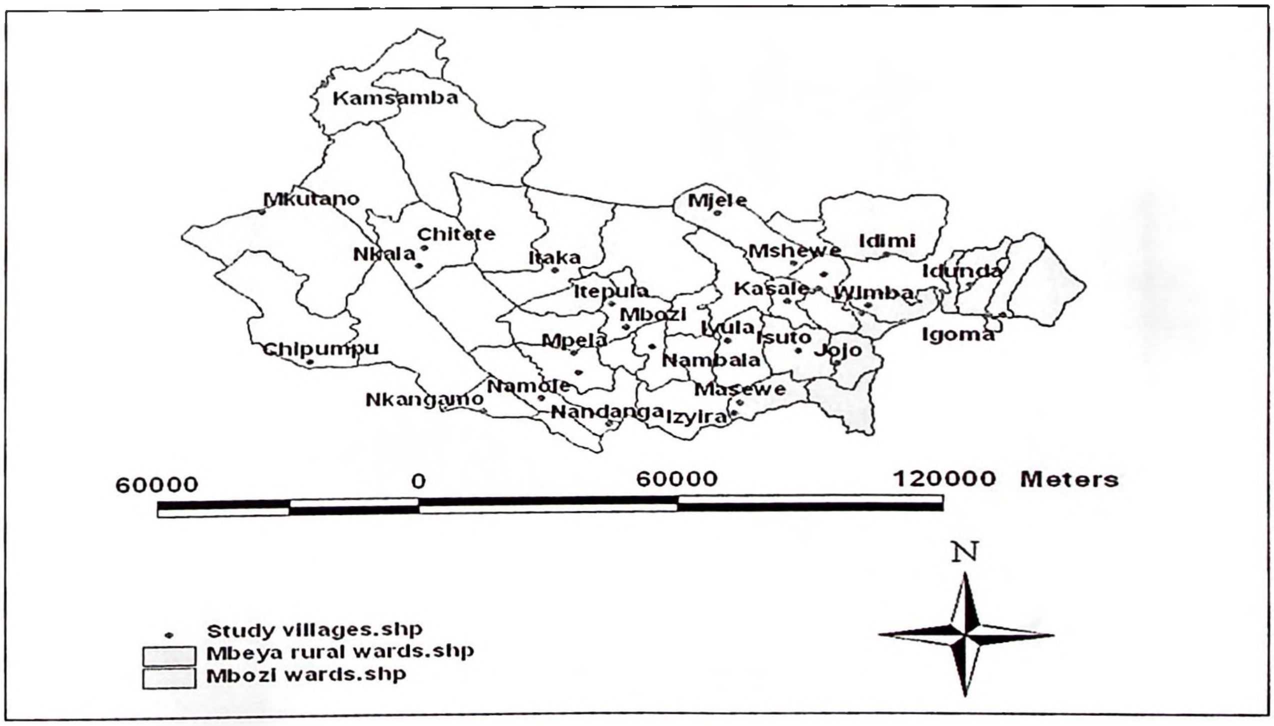

Figure 10: Mbeya and Mbozi map showing wards and distribution of study villages in cross sectional study for pig keepers

Data collection

The questionnaire was designed to collect data aimed at characterising smallholder pig production systems, experience and risk factors associated with the transmission of PC in smallholder production systems, pig marketing chain characteristics at producers (pig keepers) level and PC prevalence at household level. Data collection was undertaken between November 2007 and January 2008 and involved physical visits to pig keepers' households where face-to-face interviews were done. The study also involved direct observation of household factors such as pig keeping conditions (i.e. different classes of pigs and shelter conditions) and household hygienic factors (e.g. presence, type, and use of latrine). The targeted interview respondents were the household heads, though in their absence other family members who could deliver the required information were involved. In this study, 71 % of respondents were the household heads (84.1 % males and 15.9 % females), 25 % wives of household heads and the remaining 4 % were other family members. On the other hand, data collection for PC prevalence included ante-mortem lingual examination and blood sampling for antigen-ELISA in live pigs (Komba, 2008). The household was declared PC prevalence positive if one or more pigs within the respective household was/were found PC positive by antigen-ELISA. Details of the methodology and results of pig-based PC prevalence are reported by Komba (2008).

Statistical data analyses

Descriptive statistical procedures such as measures of central tendency (mean, frequency distribution and percentages), measure of dispersion (standard deviation, range) and cross tabulation between variables were used to summarise data, create new parameters and establish other initial inferences. Descriptive statistics were performed using statistical software originally known as Statistical Package for the Social Sciences (SPSS® version 12), (SPSS for Windows, 2003).

Pearson's chi - square test was used to assess the significance of binary relationship for nominal and ordinal variables (i.e. districts similarity and variation among socio-economic variables). Correlation analysis was used to test the strength and direction of linear relationship between two random variables of interest such as awareness of pig keepers/pig traders on PC and pig keeping/pig business activity. In the course of controlling confounding effect(s) for multiple variables of interest partial correlation was used (e.g. correlation of pig age and weight on the price).

Simple and multiple regression analyses were used to explore relationship between independent (predictors) and continuous dependent variable(s). For example, relationship between land size and herd size and relationship between price and different age and weight groups of pigs purchased by pig keepers.

Logistic regression analysis was used to predict a discrete outcome from a set of continuous or discrete (e.g. dichotomous) variables. Different logistic models such as simple, multiple logistic regressions (MLR) and multinomial logistic regressions were used depending on the nature and form of relationship needed to be analysed. MLR was preferably used to analyse multiple independent variables and adjustment for confounding effects of the other variable(s). Logistic predictor variables in MLR were organised into groups (clusters) addressing similar themes. For example when assessing risk factors for PC, predictor variables were organised into different clusters i.e. socio-economic variables, pig management systems and practices variables, awareness and knowledge on PC in pigs and human variables, and hygienic variables (water access, source and use, and latrine presence, type and use). Multinomial logistic regression was used to analyse relationship where categorical or discrete dependent outcome has more than two levels (i.e. relationship between different management systems as outcome with other factors such as household socio-economic factors). Chi square test, correlation, regression, and logistic regression analyses were done using STATA 10 data analysis and statistical software (Stata Corp. 2007).

General liner model (GLM) procedure of SAS® (SAS Institute Inc., Cary, NC) was used to analyse univariate and multivariate analysis of variance such as, the influence of household socio-economic factors (age, size, education level, gender, marital status, and land size on household pig herd size. Least Square Means (LSMeans) were compared using probability difference (PDIFF) of SAS. Means were tested using Least Square Difference (LSD). Various models were used to establish relationship between dependent and independent factors/variables of interest such as;

- Effect of location (districts) and socio-economic factors such as household size, gender of household head, marital status of household head, land size, education level of household head, and age of household head on pig herd size of smallholder pig keeper

$$Y_{ijkmnpqr} = \mu + D_j + H_k + G_m + M_n + L_p + E_q + A_r + \varepsilon_{jkmnpqr}$$

Where:

Y_{ijkmnp} = Observation of i^{th} household pig herd size in j^{th} district having k^{th} household size, m^{th} gender, n^{th} marital status, p^{th} land size, q^{th} education level, and r^{th} age

μ = overall mean,

D_j = effect of the j^{th} district

H_k = effect of the k^{th} household size

G_m = effect of m^{th} gender

M_n = effect of n^{th} marital status

L_p = effects of p^{th} land size

E_q = effect of q^{th} education level

A_r = effect of r^{th} age

ε_{jkmnp} = random/residue effect

- Effect of location and household socio-economic variables on adoption of different pig management systems (using multinomial logistic regression)

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

Where,

$Y = 0$ if the pig keeper using total confinement (TC) management system,

$Y = 1$ if the pig keeper using semi confinement (SC) management system.

$Y = 2$ if pig keeper is using free range and/or herding (FRH) management system

α = intercept,

$\beta_1 \ldots \beta_6$ = coefficients of predictor variables $X_1 \ldots X_6$

X_n = is vector of independent variable such as;

X_1 = district where pig keeper is residing (0 = Mbeya rural, 1 = Mbozi)

X_2 = education level of pig keeper (0 = secondary, 1 = primary, 2 = non- formal)

X_3 = land size (ha) of pig keepers' household (0 = 0.01 – 2, 1 = 2.01 – max)

X_4 = household pig herd size (0 = 1 – 4.9, 1 = 5 – max)

X_5 = number of goats per household (0 = none, 1 = 1 -2, 2 = above)

X_6 = number of cattle per household (0 = none, 1 = 1 -2, 2 = above 2)

- Effects of location and seasons of the year on number of pigs involved in different management systems

$$Y_{ijk} = \mu + D_j + S_k + (D*S)_{jk} + \varepsilon_{ijk}$$

Where,

Y_{ijkmnp} = Observation of i^{th} pig in j^{th} district within k^{th} season

μ = overall mean,

D_j = effect of the j^{th} district

S_k = effect of the k^{th} season

$(D*S)_{jk}$ = interaction effect of j^{th} district and k^{th} season

ε_{ijk} = random/residue effect

- Effect of different factors such as socio-economic factors, pig management systems and practices, and household hygienic factors on the prevalence of PC in smallholder pig keepers' households (using multiple logistic regression)

$$Y = \alpha + \sum \beta_n X_n$$

Where:

Y = 0, if the pig keepers' household has non infected pig(s) (negative PC prevalence)

Y = 1, if the pig keepers' household has one or more PC infected pig(s) (positive PC prevalence)

α = intercept

β_n = coefficients of predictor variables explaining the importance (risk or protection value) of variable X

X_n = vector of predictor variable such as:

- Socio-economic factors: X_1 = marital status (married = 0, non married = 1), X_2 = education level (secondary = 0, non formal = 1, primary = 2), X_3 = gender (male = 0, female = 1), X_4 = age (18 – 37 = 0, 38 – 57 = 1, 57 – 90 = 2)
- Pig management systems and practices: X_1= management systems (total confinement = 0, semi confinement and free range = 1), X_2 = type of pig shelters (concrete floor = 0, earthed floor = 1, slatted raised floor = 2), X_3 = condition of shelters (strong = 0, weak = 1), X_4 = wall condition (strong = 0, weak = 1), X_5 = floor condition (strong = 0, weak = 1)
- Household hygienic factors: X_1 = presence of latrine in the household (yes = 0, no = 1), X_2 = condition of latrine (strong = 0, poor = 1), X_3 = presence of human faeces around latrine or homestead (no = 0, yes = 1), X_4 = sources of

water (tape water = 0, borehole = 1, springs = 2, river = 3, ponds = 4), X_5 = distance to water sources (201– 800 m = 0, less than 200 m = 1, greater than 800m = 2)

3.2.1.2 Study 3: Longitudinal study among smallholder pig keepers

Study area

A Longitudinal study was carried out using 40 pig keepers' households in Mbozi and Mbeya rural districts (Fig. 9) from January to August 2008.

Study design and sampling procedure

A longitudinal, panel design was used to collect data on parameters which required extended period of monitoring of pig keepers' households (ILCA, 1990; Frees, 2004). The study involved multiple subjects in repeated observations for the eight months, that is, four wet period months (Jan – April 2008) and four dry period months (May – August 2008). The study used the household as an independent farm and as a unit of observation. The study was designed to gather quantitative and qualitative information addressing monthly and seasonal (dry and wet) household pig production and marketing dynamics.

The sample villages and households involved in the study were selected proportionally from cross sectional study sample frame (section 3.2.1.2). Ten villages (five villages from each district) representing 33.3 % of villages involved in the cross-sectional study were selected (Mukhebi *et al.*, 1999). Thereafter, four households in each selected village were randomly selected to give 20 monitored households per district

Data collection and parameter estimations

A baseline dataset was established at initial stage of data collection. Thereafter, consecutive monthly observations within and between dry and wet seasons were undertaken. In each month, cumulative monthly data were recorded by the researcher once a month preferably at the end of the month. Participating households were trained on how to keep important pig records and were provided with simple record cards for recording purposes. Data collection method involved physical observations of pig herd structure and inventory trend, and focused household interviews to elicit information and to ascertain some recorded/observed data and/or events. Main data collected include pig herd dynamics (i.e. herd structure, pig acquisition and disposal), interspecies composition, disease incidences and mortalities, management practices and performance. A designed form (Appendix 3) guided data collection

A number of parameters were derived from the original data. Different pig off take coefficients such as gross off take, annual gross off take rate, annual sales rate (commercial off take rate), net off take and annual net off take rate were estimated using the following formulae:

$$\text{Gross off take in period }(t) = (\text{Live sales} + \text{leased out} + \text{slaughter})\text{ during period }(t) \ldots\ldots \quad (i)$$

$$\text{Gross off take rate }(\%) = \frac{\text{Gross off take in period }(t)}{\text{Mean herd size }(t)} \times 100 \ldots\ldots\ldots \quad (ii)$$

$$\text{Annual sales rate/commercial off take rate }(\%) = \frac{\text{Pig sales in period }(t)}{\text{Mean herd size }(t)} \times 100 \ldots\ldots\ldots \quad (iii)$$

$$\text{Net off take in period }(t) = (\text{Gross off take} - \text{acquisition})\text{ in period }(t) \ldots\ldots\ldots \quad (iv)$$

$$\text{Net off take rate in period }(t)\ \% = \frac{\text{Net off take in period }(t)}{\text{Mean herd size }(t)} \times 100 \ldots\ldots\ldots \quad (v)$$

Mean herd size was calculated as the number of animal–days per monitoring period in days. Number of animal-days is the sum of the number of days that each animal in the observed population is present during a period of monitoring (Chikagwa-Malunga and Banda, 2006).

Statistical data analysis

Descriptive statistical procedures such as frequency, percentages, means, standard deviation, range and cross tabulation across variables was used to summarise the data. Data analyses were done using SPSS statistical analysis software. MLR was used to analyse the use of different production systems in different districts at different seasons using STATA 10 analytical software. GLM procedure of SAS was used to analyse the effects of various class variables such as districts, seasons of the year and PC prevalence status on the continuous dependent variables such as pig disposal, off take, and performance variables. Least Square Means (LSMeans) were compared using probability difference (PDIFF) of SAS. Means were tested using Least Square Difference (LSD). Model used was as follow;

- The effects of districts and households PC prevalence status on pig off take variables in smallholder pig keepers

$$Y_{ijk} = \mu + D_j + P_k + (D*P)_{jk} + \varepsilon_{jk}$$

Where;

Y_{ijk} = Observation of i^{th} household pig off take variable in j^{th} district having k^{th} PC prevalence

μ = overall mean,

D_j = effect of the j^{th} district

H_k = effect of the household k^{th} PC prevalence

$(D^*P)_{jk}$ = interaction effect of j^{th} district and k^{th} PC prevalence

ε_{ijk} = random/residual effect

1.2.1.3 Study 4: Cross – sectional survey of pig traders

Study area

A cross–sectional study focusing on pig traders was carried out in Mbozi, Mbeya rural and Mbeya urban in Mbeya region (cf. section 3.1.2).

Study design and sampling procedure

A single visit-multiple subject's procedure cross-sectional design was used to collect data from pig market participants using structured questionnaires (Appendix 4,5 &.6). The study focused mainly on pig traders at intermediate and terminal levels of pig marketing chain (ILCA, 1990; Williams *et al.,* 2006).

Three districts were purposively selected to establish the inter-linkage between pig production (studies 1-3) and marketing. Moreover, Mbeya urban was included in order to establish commodity flow chain characteristics from district villages to the urban environment. Therefore, 36 % (n =24) of sampled villages in this study included 80 % of (cross sectional sampling frame) villages participating in cross sectional study for pig keepers. The remaining 64 % (n = 43) of villages were randomly sampled based on location setting of pig business within the respective districts. Hence, the study involved 67 villages from 42 wards whereby 124 pig traders from five categories of pig trading were selected for interview.

Prior to the selection of participating villages and respondents, preliminary reconnaissance surveys was done in the respective districts for the purpose of general appraisal of pig marketing and thus established sample frames, profiles of market participants and major features of pig marketing from village to urban level. Since there was no defined market places for pigs in the study areas, the pig traders were selected based on their pig business profiles, location setting of their pig business and their relative distribution in a study areas (Table 15).

Table 15: Type of pig traders sampled in cross section survey for pig traders, their profiles of pig trading and distribution of sample frame in the study districts

Type of pig traders	Profile/characteristics of pig traders	District			Total
		Mbeya urban	Mbeya rural	Mbozi	
Butchers	• Sale mainly fresh pork	13	5	1	19
Pork processors	• Sale mainly processed pork	11	4	3	18
Pork centre operators	• Sale both fresh and processed pork	1	21	48	70
Pig transporters	• Buy and transport live pigs to other regions of Tanzania especially Dar –es-salaam	6	3	-	9
Pig retailers	• Buy and sell live pigs to other traders	-	4	-	4
Pig collecting agents	• Intermediary agents buying pigs on behalf of other traders, mainly transporter	-	2	2	4
Total		31	40	54	124

Data collection

Data collection was undertaken between August and December 2007 using structured questionnaires specific for each category of pig trader. The survey involved physical visits to pig traders' working/business places where both face-to-face interviews and observation were carried out. In some places, physical observations of slaughtering background were observed. Since there was no specific market place for marketing pigs where pig market data such as pig weights, ages and prices could be conveniently collected, different strategies were used to collect such data depending on the prevailing environment. Among strategies used include; the use capability of the traders to recall most important pig transaction carried out in previous period. Other startegies were physical measurement (weight estimate using weight calibrated tape measure) for pigs bought and yet to be slaughtered and price bargaining imitation between nearby pig keeper and pig trader, thereafter physical measurement of weight and recording of age and price was undertaken by researcher.

Data collected included: general description of area and socio-economic characteristics of pig traders, sources of pigs/pork, purchasing conditions and prices. Other data were; pig and pork selling conditions, prices and criteria for quality and prices, awareness, knowledge and experience of pig keepers on PC and pig slaughter and inspection status (Questionnaires for respective pig traders showing detailed data collected are shown in Appendix 4, 5 & 6).

Statistical data analyses

Data analyses involved descriptive statistical procedures as described in section 3.2.1.2. Pearson's chi square was used to analyse significance of binary relationship of nominal and ordinal variables such as variation of status of awareness and knowledge on PC among pig traders in different districts. Simple and partial correlation were used to analyse relationship between and among variables of interest along pig marketing chain, such as, relationship between prices paid to pigs and pig ages and weights purchased by pig traders and relationship between pig business and awareness on PC.

Logit regression analysis was used to assess the relationship between dichotomous response variable and set(s) of explanatory variables such as variation of traders' experiences on PC in different districts and type of pig business. GLM procedure of SAS was used to analyse the effects of various class variables in the pig traders' environment such district, type of pig business and location of pig business on dependent variable(s) such as the mean monthly number of pig purchased by pig traders. Least square means were compared using probability difference (PDIFF) of SAS and means were tested using LSD.

CHAPTER FOUR

4.0 RESULTS

4.1 Smallholder Pig Production Systems

4.1.1 Demographic and socio-economic characteristics of smallholder pig keepers

4.1.1.1 Marital status and education level

Table 16 shows gender, marital status and education levels of pig keepers' household heads in the study districts. Most (85.3 %) of pig keepers household head were males, with relatively few female headed households. There was no significant difference between districts on the gender of household head ($P > 0.05$). Majority (85.3 %) of pig keepers households' heads were married, while, comparatively few of them were widowed. There was no significance different on marital status between study districts ($P> 0.05$). Most of pig keepers had primary education, though few had no formal education. There was no statistical difference between study districts with regard to education status ($P>0.05$).

Table 16: Gender, marital status and education levels of pig keepers' household head in the study districts

Gender, marital status and education level	Mbozi N1 = 151 n (%)	Mbeya rural N2 = 149 n (%)	Total N = 300 n (%)	Chi-square and P value
Gender of HH				
Male	131 (86.8)	125 (83.9)	256 (85.3)	$\chi^2 = 0.49$, P = 0.48
Female	20 (13.3)	24 (16.1)	44 (14.7)	
Marital status of HH				
Married	130 (86.1)	126 (84.6)	256 (85.3)	$\chi^2 = 5.05$
Single	3 (2.0)	1 (0.7)	4 (1.3)	P = 0.17
Widowed	18 (11.9)	18 (12.1)	36 (12.0)	
Divorced	0 (0.0)	4 (2.7)	4 (1.3)	
Education level of HH				
No formal education	24 (15.9)	31 (20.8)	55 (18.3)	$\chi^2 = 1.47$
Primary	115 (76.2)	109 (73.2)	224 (74.7)	P = 0.48
Secondary O-level	12 (8.0)	9 (6.0)	21 (7.0)	

N= entire sample count/respondents, Ni (i = 1, 2, 3.....) = sub-sample count/respondents, n = affirmative count/respondents to a particular question. The same description holds for the subsequent Tables bearing the similar circumstance.

4.1.1.2 Household size and composition

Household size and composition for different age groups of pig keepers' households in the study districts is shown in Table 17. Age of pig keepers' household heads ranged between 18 to 90 years, with mean of 41.6 ± 13.3 years. Mean households head ages between study districts were not statistically (P > 0.05) different. On the other hand, overall mean household size for smallholder pig keepers was 6.0 ± 3.1 persons. However, variations were observed among different household age groups.

Table 17: Household size (number of persons) and composition for different age groups of pig keepers in the study area

HH age group (years)	Mbozi		Mbeya rural		Total	
	Mean ± s.d	%	Mean ± s.d	%	Mean ±s.d	%
Under 7	1.7± 1.4	26.8	1.4 ± 1.3	25.4	1.6 ± 1.3	26.1
7 – 14	1.5 ± 1.5	24.3	1.5 ± 1.2	25.8	1.5 ± 1.4	25.0
15 – 21	0.9 ±1.1	13.7	0.7 ± 1.1	12.6	0.8 ± 1.1	13.2
22 – 55	2.0 ± 1.0	31.0	1.9 ± 1.0	33.3	1.9 ± 1.0	32.1
Above 55	0.3 ± 0.7	4.3	0.2 ± 0.4	2.9	0.2 ± 0.6	3.6
Total household size	6.4 ± 3.4	100.0	5.7 ± 2.8	100.0	6.0 ± 3.1	100.0

4.1.1.3 Land size and distribution

Table 18 shows the mean land size owned by pig keepers in the study districts. Mean land size owned and distribution varied among pig keepers and between districts (P < 0.001). Land size owned by pig keepers in both districts varied between 0.1 and 32.4 ha with mean of 2.0 ha per household. Pig keepers in Mbozi district significantly owned bigger land size (2.6 ± 0.2 ha) than their counterparts in Mbeya rural district (1.3 ± 0.2) (P< 0.001). Land size distribution is shown in the Table 19. Majority (65 %) of pig keepers possessed land below 2.0 ha, but 51 and 80 % of pig keepers in Mbozi and Mbeya rural respectively owned land of similar size.

Table 17: Mean land size holding (ha) by pig keepers in the study districts

District name	N	Land size (ha) Mean ± SE	P value and significant
Mbozi	151	2.6 ± 0.2^{a}	$P < 0.001$***
Mbeya rural	147	1.3 ± 0.2^{b}	
Total	298	2.0	

Means within the same column having different superscripts (a & b) are significantly different ($P< 0.001$).

Table 18: Land size distribution among pig keepers in the study districts

Land size (ha)	Mbozi (N1 = 151)	Mbeya rural (N2 = 149)	Total (N = 300)
	%	%	%
0.01 – 1	19.9	43.5	31.5
1.01 – 2	31.1	36.1	33.6
2.01 – 4	31.8	17.0	24.5
4.01 - max	17.2	3.4	10.4
Chi square and P value	$\chi^2 = 36.99$, $P = 0.001$***		

4.1.1.4 Economic activities of smallholder pig keepers under a crop-livestock integrated system

Crop cultivation ranked first among important economic activities done by smallholder pig keepers (Table 20). Livestock keeping and petty business ranked second and third, respectively as important pig keepers activities in both districts. Other important activities include casual labour and artisan, which ranked fourth and fifth, respectively. Other economic activities include salaried employment, charcoal making, sewing and weaving, timber works, and fishing.

Table 19: Main and important economic activities performed by pig keepers in study districts using PRA pair-wise matrix ranking

Economic activity	Mbozi		Mbeya rural	
	Score	Rank	Score	Rank
Crop cultivation	35	1	36	1
Livestock keeping	31	2	31	2
Petty business	27	3	26	3
Casual labour	18	4	18	4
Artisan	17	5	17	5
Salary employment	15	6	9	6
Charcoal making	10	7	8	7
Sewing and weaving	9	8	7	8
Timber work	8	9	2	9
Fishing	1	10	1	10

4.1.1.5 Main livestock kept and importance of pig keeping in the system

Main livestock kept and their importance in the farming systems involving pig keepers are shown in Table 21. Based on farming systems of pig keepers in both districts, pig keeping ranked third after cattle and goats among the important livestock kept in the system. The scores between goats and pigs in Mbeya rural district were relatively closer than in Mbozi districts. Table 22 shows main livestock types kept by pig keepers, proportion (percentage) of households keeping such livestock and mean number per household. The importance of cattle, goats, pigs, and local chicken was also reflected in the percentage of pig keepers keeping such livestock (Table 22). There was no significant difference on the percentage of pig keepers keeping local cattle and goats between the two districts ($P > 0.05$). However, the mean number of local cattle and chicken were significantly higher in Mbozi district than in Mbeya rural district ($P < 0.036, 0.001$, respectively)

Table 20: Main livestock kept and their importance in pig keepers' farming system

Type of livestock kept	Mbozi (Importance)		Mbeya rural (Importance)	
	Score	Rank	Score	Rank
Local cattle [1]	43	1	36	1
Goats	40	2	29	2
Pigs	35	3	28	3
Local chicken	32	4	26	4
Sheep	24	5	19	5
Ducks	13	6	5	8
Donkey	9	7	3	10
Turkey	8	8	4	9
Dairy cattle [2]	4	9	13	6
Rabbits	3	10	6	7

[1] mainly Tanzania short horn zebu, [2] mainly crosses of local and exotic

Table 21: Main types of livestock kept by pig keepers' households

	Mbozi	Mbeya rural	Total	Test and P- value
Proportion of households keeping	N1=151 n (%)	N2 = 149 n (%)	N= 300 n (%)	P value for chi square test
Local cattle	69 (46)	53 (36)	122 (41)	0.074
Goats	70 (46)	62 (42)	132 (44)	0.406
Local chicken	137 (91)	93 (62)	230 (77)	< 0.001***

Mean number of livestock per household

	mean ± SE	mean ± SE	Total	F-test
Local cattle	3.4 ± 0.68^a	1.3 ± 0.68^b	2.4	0.036*
Goats	2.1 ± 0.32^a	2.0 ± 0.32^a	2.1	0.812
Local chicken	8.6 ± 0.62^a	5.0 ± 0.62^b	6.8	< 0.001***

[1] number of households, * significant (P<0.05, *** (P<0.001)

4.1.2 Trend and reasons for pig keeping by smallholder pig keepers

4.1.2.1 Trend of pig keeping by smallholder pig keepers

Figure 11 shows pig keeping experience among smallholder pig keepers' households in Mbozi and Mbeya rural. Some pig keepers started pig keeping way back in 1971, however, majority (79 %) were engaged in pig keeping in recent years between 2000 and 2007 compared to few (21 %) who started pig keeping 28 years back (1971- 1999).

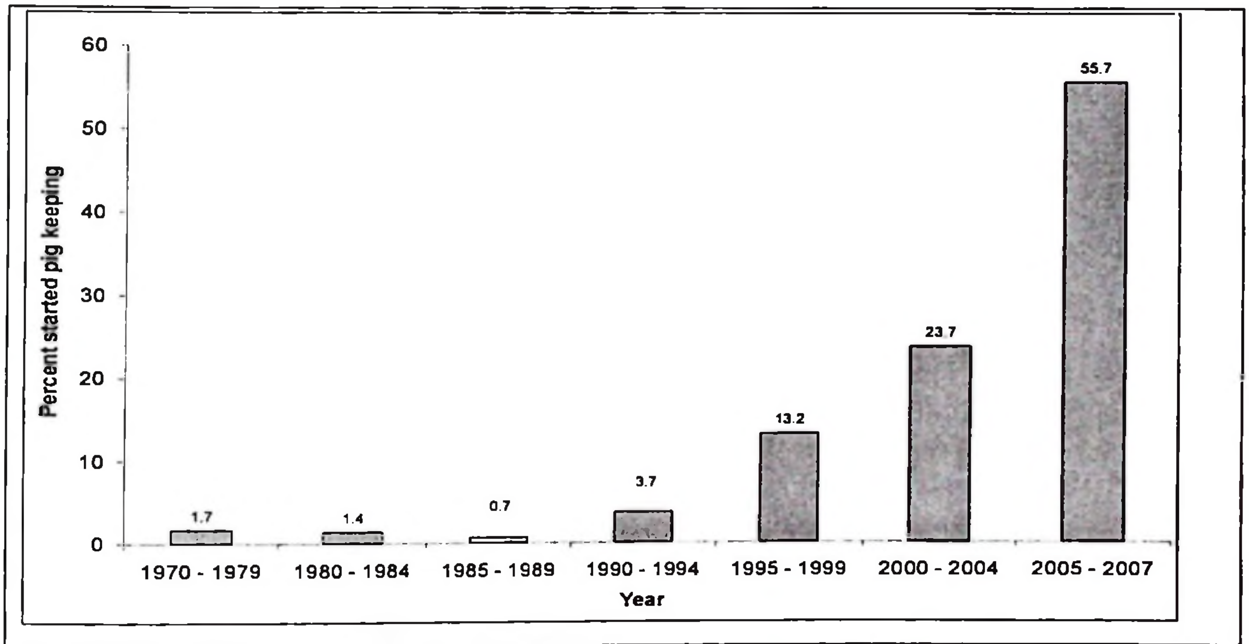

Figure 11: Proportionate pig keeping experience among smallholders in Mbozi and Mbeya rural districts

4.1.2.2 Reasons for pig keeping by smallholder pig keepers

Main reasons for pig keeping by smallholder farmers are shown in Figure 12. All respondents narrated cash income from pig sale as main reason for keeping pigs. Other important reason was manure production which expressed by 49 % of respondents. Only few pig keepers expressed pig slaughter for home consumption and cultural reasons as important reasons for keeping pigs.

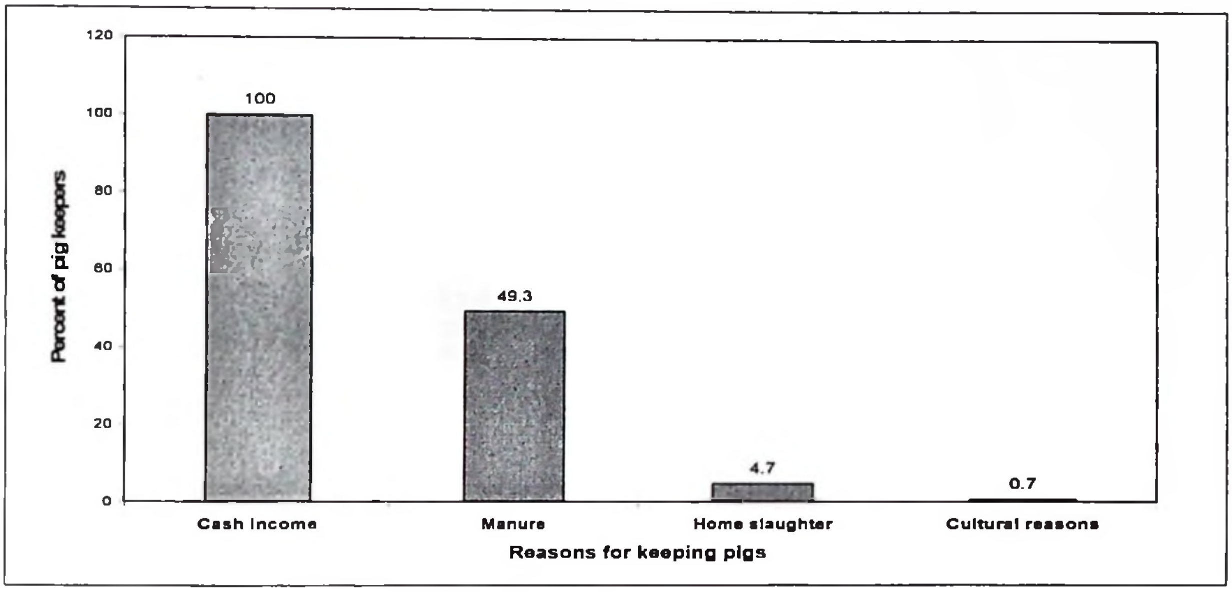

Figure 12: Main reasons for keeping pigs

4.1.3 Pig herd size and structure in smallholder pig production system

4.1.3.1 Pig herd size

Herd size distribution in smallholder farmer's households

Table 23 shows pig herd size distribution in smallholder pig keepers' households in the study districts. Pig herd size across the study districts varied between 1 and 31 with mean of 4.9 ± 4.2. Herd size distribution varied between districts and households. Mbozi district had significantly ($P < 0.01$) higher mean herd size than Mbeya rural district. Similar pattern was also observed on herd size distribution between two districts. Majority (60 %) of pig keepers' households in both districts had herd size between 1 and 4 pigs, such that 35 % of pig keepers had 1 - 2 pigs with mean of 1.7 ± 0.5 pigs per household, while, 25 % had 3 – 4 pigs with mean number 3.5 ± 0.5 pigs per household. On the other hand, 30 % of pig keepers' households had herd size between 5 and 10 pigs.

Table 22: Pig herd size distribution in pig keepers' households in the study districts

Herd size	Mbozi (N1 = 151)		Mbeya – rural (N2 = 149)		Total (N = 300)	
	Percent of households	Mean herd size ± s.d	Percent of households	Mean herd size ± s.d	Percent of households	Mean herd size ± s.d.
1 - 2	30	1.7 ± 0.5	40	1.6 ± 0.5	35	1.7 ± 0.5
3 – 4	24	3.3 ± 0.5	27	3.6 ± 0.5	25	3.5 ± 0.5
5 – 6	18	5.5 ± 0.5	13	5.4 ± 0.5	15	5.5 ± 0.5
7 – 10	15	8.1±1.2	15	7.9 ± 1.1	15	8.0 ± 1.1
Above 10	14	14.9 ± 5.0	5	14.0 ± 3.3	10	14.6 ± 4.6
Total	100.0	5.5 ± 4.7	100.0	4.2 ± 3.3	100.0	4.9 ± 4.15

Influence of districts and socio-economic factors on pig herd size

Results showing the effect of districts and smallholder socio-economic factors on pig herd size are presented in Tables 24 and 25. Education level and gender of household head had no significant effects on the household pig herd size ($P > 0.05$). Age of household head had significant influence on the household herd size ($P < 0.05$). Middle age groups with ages between 28 and 57 years had significantly ($P< 0.05$) larger mean pig herd size than their counterparts with relatively young ages below 27 and above 58 years. Moreover, among the middle age groups, pig keepers with age between 28 and 37 had significant larger mean herd size than their counterparts with age between 48 and 57 years ($P<0.05$).

Generally, mean herd sizes increased consistently with increased household size, up to household size of nine individuals. Household size between seven and nine individuals had significantly larger mean herd size than those with household size below six individuals ($P < 0.05$). Marital status showed an influence on household pig herd size whereby divorced pig keepers' household had significantly ($P<0.05$) lower mean herd size compared to single households. Married, singles and widowed had no significance differences on pig herd size ($P>0.05$).

Relationship between land and pig herd size is presented in the Table 26. Household land size had significant ($P< 0.05$, $\beta = 0.09$) positive influence on pig herd size. Household with land size above four ha had significantly bigger herd size compared to their counterparts with land size below four ha ($P < 0.05$).

Table 23: Effect of districts, age, household size, and education on the household pig herd size

Factors	Number of household N = 300	Percent	Herd size LSM[1] ± SE
District			
Mbozi	151	50.3	5.5± 0.3 [a]
Mbeya rural	149	49.7	4.2 ± 0.3 [b]
Age groups of household head (years)			
18 - 27	34	11.4	5.0 ± 2.8[c]
28 – 37	91	30.5	7.2 ± 1.7[a]
38 – 47	89	29.9	6.1 ± 1.7[ab]
48 – 57	47	15.8	5.7 ± 2.4[b]
58 – 67	21	7.0	3.7 ± 3.6[c]
68 -Max	16	5.4	4.5 ±4.5[c]
Household size (individuals)			
1-3	57	19.0	4.4 ± 0.9[b]
4- 6	133	44.3	4.6 ± 0.6[b]
7 – 9	82	27.3	5.6 ±0.8[a]
10 - max	28	9.3	5.1 ±1.3 [ab]
Education level of household head			
No formal education	55	18.3	5.4 ± 0.5[a]
Primary education std 4	45	15.0	5.3 ± 0.6 [a]
Primary education std 7/8	179	59.7	4. 6 ± 0.3[a]
Secondary education O-level	21	7.0	5.4 ±0.9[a]

[1] Least square means. Means within the same column having different superscripts are significantly different (P< 0.05)

Table 24: Effect of gender, marital status, and land size of pig keepers on the pig herd sizes

Factors	Households N = 300	Percent	Herd size LSM ± SE
Gender of household head			
Male	256	85.3	5.0 ± 0.3^{a}
Female	44	14.7	5.1 ± 0.7^{a}
Marital status of household head			
Married	256	85.3	4.8 ± 0.3^{ba}
single	4	1.3	7.7 ± 2.1^{a}
widowed	36	12.0	5.1 ± 0.7^{ba}
Divorced female	4	1.3	2.4 ± 2.1^{b}
Land size (ha)			
0.01 – 1	94	31.5	4.5 ± 0.5^{b}
1.01 – 2	100	33.6	4.7 ± 0.47^{b}
2.01 – 4	73	24.5	4.2 ± 0.55^{b}
Above 4	31	10.4	5.9 ± 0.84^{a}

Means within the same column having different superscripts are significantly different ($P < 0.05$)

Table 25: Regression between land size and pig herd size in the study districts

Land size (ha)	Coefficient (β)	SE	T value	Probability	95% Conf. Interval
Herd size	0.09	0.037	2.47	0.014*	0.018 – 0.163
constant	1.51	0.236	6.41	< 0.001***	1.048 – 1.978

* Significant ($P < 0.05$), *** ($P < 0.001$)

4.1.3.2 Pig herd structure

Table 27 shows pig herd structure in smallholder pig keepers' households. Five herd structure categories were identified, namely, adult breeding stock, adults' non-breeding stock, pre-weaned piglets, weaners and growers stock. Breeding females (sows) had a largest proportion in the smallholders herd structure with mean number of 0.98 ± 0.96 per household and owned by majority (66.7%) of pig keepers. Mean age of breeding females was 22.2 ± 9.1 months with majority (66 %) of them having ages between 16 and 30 months. Pre-weaned piglets was second largest pig class owned by 50 % of pig keepers with mean number of 0.85 ± 1.88 males and 0.80 ± 1.73 females' piglets per household. Mean age at weaning was 89.6 ± 20.6 days. A relative higher proportion of pig keepers owned weaners and growers females compared to weaners and grower non-castrated and castrated males. Relatively few pig keepers' households owned breeding boars. Breeding boar had lower mean age (16.1± 4.3 months) than breeding females (sows). Other pig classes owned by very few (less than 5 %) households and with low mean number per household (less than 0.06) were adults' non-breeding herd (non-castrated males, castrated males and females).

Table 26: Pig herd structure in smallholder pig keeper's households

Herd structure category	Pig class composition	Households kept the pig class (N = 300)	Mean and percent of pig class per household	
		Percent	Mean ± s.d.	Percent
Adults breeding stock	Sows	66.7	0.98 ± 0.96	20.0
	Boars	12.7	0.15 ± 0.44	3.1
Adults non breeding stock	Non - castrated males	3.7	0.05 ± 0.27	1.0
	Castrated males	1.7	0.03 ± 0.21	0.6
	Females	0.7	0.01 ± 0.18	0.2
Pre-weaned piglets	Males	25.0	0.85 ± 1.88	17.3
	Females	25.0	0.80 ± 1.73	16.3
Weaners	Females	27.0	0.55 ± 1.10	11.2
	Non-castrated males	23.0	0.50 ± 1.15	10.2
	Castrated males	2.3	0.05 ± 0.34	1.0
Growers	Females	34.0	0.52 ± 0.89	10.6
	Non-castrated males	18.0	0.27 ± 0.66	5.5
	Castrated males	10.3	0.14 ± 0.47	2.9
	Total		4.9 ± 4.15	100.0

4.1.4 Smallholder pig production systems and their classification

Smallholder pig production systems in study districts were classified broadly into three management types: Total confinement (TC), semi-confinement (SC) and free range/herding (FRH). Feeding and sheltering were used as primary factors in management systems classification. In TC system, pigs were confined in the shelter throughout the year. Households practising TC management system had permanent shelter(s) for pigs whereby pigs were stall-fed in their pens. In SC system, pigs were partially confined in their shelters or tethered depending on periods of a day and/or seasons of the year. Most households practising SC system had semi- permanent pig shelters. In FRH system, pigs were allowed to roam freely and/ or herded in most periods of the year. Households practising the system had either none or semi-permanent pig shelters.

4.1.4.1 Characteristics and influences of different factors on distribution of smallholder pig management systems

Land, livestock and household size characteristics and distribution in smallholder pig management systems

Table 28 shows land, livestock and household size characteristics and their distribution in different pig management systems. SC and TC were the dominant management systems used by majority (91.3 %) of pig keepers with SC been relatively practiced by more pig keepers, and followed by TC. Relatively fewer pig keepers practiced FRH. Mean household size, land size and pig herd sizes varied across different pig keepers' management systems. Mean household size, land size, pig herd sizes were consistently higher in households practising FRH, followed by households practising SC, and lastly lower in households practising TC management system. About 41 and 44 % of smallholder pig keepers keep also local cattle and goats, respectively. Moreover, relatively larger proportion of households practicing FRH keep cattle and goats compared to those practising SC and TC. Similar trend was also observed in mean number of cattle and goats kept by pig keepers across the three management systems. Local chickens were among the livestock class kept by majority of pig keepers. Mean number of chicken per households was higher for pig keepers practising FRH management system compared to those practising SC and TC system.

Table 27: Land, livestock, and household size characteristics in different pig management systems

Characteristics	Management systems			
	TC (N1 =126) n (%)	SC (N2 = 148) n (%)	FRH (N3 = 26) n (%)	Total (N = 300) n (%)
Proportion of household				
Practised the system	126 (42.0)	148 (49.3)	26 (8.7)	300 (100.0)
Keeping cattle	42 (33.3)	64 (43.2)	16 (61.5)	122 (40.7)
Keeping goats	49 (38.9)	67 (45.3)	16 (61.5)	132 (44.0)
Keeping chickens	83 (65.9)	121 (81.8)	26 (100.0)	230 (77.0)
Mean per household (mean ±s.d)				
Household size	5.9 ± 3.0	6.0 ± 3.3	6.4± 2.4	6.0 ± 3.1
Land size (ha)	1.5 ± 2.3	2.3 ± 2.9	2.7± 2.4	2.0 ± 2.6
Pig herd size	4.5 ± 3.7	4.9 ± 4.3	6.8 ± 5.1	4.9 ± 4.2
Number of cattle	2.4 ± 12.1	2.1 ± 3.7	3.7 ± 4.7	2.4 ± 8.3
Number of goats	1.7 ± 2.9	2.1± 3.9	4.1 ± 6.4	2.1 ± 3.8
Number of chicken	6.4 ± 8.4	6.5 ± 6.7	10.6 ± 9.9	6.8 ± 7.8

The effects of different factors on the distribution of smallholder pig management systems

Table 29 shows the effects of location (districts), education level, land size, pig herd size, number of goats and cattle on the use of different pig management systems by smallholder pig keepers. Types of pig management systems and distribution among different location and socio-economic factors are shown in Appendix 7. Semi confinement (SC) management system was significantly more practised by pig keepers in Mbozi (62.3%) than Mbeya rural districts (36.2) (OR = 4.9, P < 0.001). Significantly more farmers with primary (52.7%) (OR = 4.1, P < 0.001) and none-formal formal (41.8 %) education practised SC system than their counterparts with secondary (33.3%) education (OR= 2.5, P < 0.001). Pig keeping households with bigger land size (land > 2 ha) significantly practised more SC (OR = 1.8) and/or FRH (OR = 1.3) systems than pig keepers with small land size (land ≤ 2 ha) who practised more TC.

Significantly more pig keepers in Mbozi than in Mbeya rural district practised FRH (OR = 66.6, P < 0.001). More pig keepers with primary and non-formal education significantly practised FRH than their counterparts with secondary education (P<0.001). Households with pig herd size above five (mean pig herd per household) significantly practised more FRH than their counterpart with pig herd size below five (OR = 3.4, P < 0.001). On the other hand, FRH management system was statistically (P > 0.05) similar for pig keepers with no local cattle and/or goats and those with one and two cattle and/or goats. However, FRH was significantly (OR = 15.6, 15.9, P < 0.001, for cattle and goats, respectively) more practiced by households with more than two cattle and/or goats than their counterparts with no cattle and/or goats.

Table 28: The effects of pig keepers' socio-economic variables on practise of different pig management systems using multinomial logistic regression

Factors	Level of factor	n[a] (%)	Odd ratio	95 % Conf. Interval	P – value and significance
SC					
District	Mbeya rural	54 (36.2)	1.0[b]		
	Mbozi	94 (62.3)	4.9	4.48 – 5.24	< 0.001***
Education level	Secondary	7 (33.3)	1.0[b]		
	Primary	118 (52.7)	4.1	2.66 – 6.26	< 0.001***
	No formal educ.	23 (41.8)	2.5	1.73 – 3.50	< 0.001***
Land size (ha)	0.01 – 2	84 (43.3)	1.0[b]		
	2.01 - max	63 (60.6)	1.8	1.64 – 1.94	< 0.001 ***
Pig herd size	1 – 4.9	87 (48.1)	1.0[b]		
	5 – max	61 (51.3)	1.4	0.92 – 2.11	0.116 NS
Number of goats	None	81 (48.2)	1.0[b]		
	1 - 2	27 (54.0)	1.1	0.99 – 1.19	0.088 NS
	Above 2	40 (48.8)	1.0	0.78 – 1.29	0.988 NS
Number of cattle	None	84 (47.2)	1.0[b]		
	1 – 2	25 (55.6)	1.4	0.41 – 4.83	0.580 NS
	Above 2	39 (50.7)	1.2	1.05 – 1.36	0.009 **
FRH					
District	Mbeya rural	1 (0.7)	1.0[b]		
	Mbozi	25 (16.6)	66.5	64.47 – 68.58	< 0.001***
Education level	Secondary	0 (0.0)	1.0[b]		
	Primary	23 (10.3)	33.0	24.3 – 62.6	< 0.001***
	No formal educ.	3 (5.5)	16.0	2.45 – 6.37.	< 0.001***.
Land size (ha)	0.01 – 2	12 (6.2)	1.0[b]		
	2.01 - max	14 (13.5)	1.3	1.27 – 1.35	< 0.001 ***
Pig herd size	1 – 4.9	8 (4.4)	1.0[b]		
	5 – max	18 (15.1)	3.7	3.50 – 3.87	< 0.001 ***
Number of cattle	None	10 (5.6)	1.0[b]		
	1 – 2	4 (8.9)	1.6	0.40 – 5.99	0.520 NS
	Above 2	12 (15.6)	1.5	1.05 – 1.36	< 0.001 ***
Number of goats	None	10 (6.0)	1.0[b]		
	1 - 2	3 (6.0)	1.0	0.71 – 1.48	0.898 NS
	Above 2	13 (15.9)	2.5	2.02 – 3.14	< 0.001***

Total confinement management system was used as reference category, [a] number of household practising the system, [b] reference odd ratio for respective factor

4.1.4.2 Main reasons influencing pig keepers to practise different management systems

Table 30 shows main reasons influencing pig keepers to use different pig management systems. Among the important reasons for practising TC were to avoid crop damage and conflict with neighbours that accounted for about 97 % of all pig keepers. General avoidance or minimisation of diseases was among the important reason for practising TC. Other reasons for TC include improving pig security, adhere to village bylaws, avoid PC infection, manure collection and control breeding.

On the other hand, feed based reasons such as feed supplementation, reducing feeding and watering cost was main reason stirred pig keepers to practise FRH system as accounted by 83 % of respondents. Other reasons include improving pig performance, to exercise pigs, lack of pig shelter or minimisation of shelter cost and conflict minimisation or avoidance which accounted for 8.5 % specifically for those practicing herding system.

Feed supplementation, reducing feeding, and watering cost were shown as main reasons for pig keepers to practise SC management system. Other reasons included exercising pigs, minimise conflicts, crop damages and fines, allow pigs search for water and reduce sheltering costs.

Table 29: Main reasons influencing pig keepers to use different management systems as expressed by pig keepers

Reasons for using different management systems	n (%)*
Reasons for pig confinement (N1 = 236)	
Avoid crop damage and conflict with neighbours	228 (96.6)
Avoid or minimise diseases	88 (37.3)
Improve pig security	30 (12.7)
Avoid to be fined/adhere to village bylaws	18 (7.6)
Avoid PC infection	13 (5.5)
Avoid destruction of properties	2 (0.8)
Manure collection	2 (0.8)
Control breeding	2 (0.8)
Reason for free ranging/herding of pigs (N2 = 129)	
Supplement feed, reduce feeding and watering cost	107 (83.0)
Improve pig performance	28 (21.7)
Exercise pigs	17 (13.2)
Lack of shelter & minimise shelter cost for pigs	11(8.5)
Conflict minimization/avoidance**	11(8.5)
Reasons for semi confinement (N3 = 87)	
Feed supplementation and reduce feeding and watering cost	90 (103.4)
Exercise pigs	30 (34.5)
Minimize conflicts, crop damages and fines	10 (11.5)
Allow search for water and wallowing	3 (3.4)
Reduce sheltering cost	2 (2.3)

* Total observation > 100 % due to multiple responses, **More specific to pig keepers practicing herding

4.1.4.3 Pig shelter in smallholder pig management systems

Types of pig shelter used by smallholder pig keepers

Table 31 shows types of pig shelters used by smallholder pig keepers in the study districts. Figure 13, 14, and 15 show different images of pig shelters used by smallholder pig keepers. Assessment of types of pig shelters was based mainly on floor types. In this context, there were mainly four types of pig shelters used by smallholder pig keepers in the study area. Earthed floor and slatted raised floor were the main types of pig shelters used by the majority (94.4 %) of pig keepers. A few pig keepers used concrete floor and slatted ground level floor pig shelters. Types of pig shelters varied between districts and management systems. Earthed floor type of pig shelters were significantly ($P < 0.001$) more common in Mbozi district (62.3 %) than in Mbeya rural district (27.9 %), while, slatted raised floor were significantly ($P < 0.05$) more common in Mbeya rural (67.4 %) than Mbozi district (31.2 %). There was no significant difference between concrete floor and slatted ground level floor types of pig shelters between the study districts ($P > 0.05$).

Table 30: Types of pig shelters used by smallholder pig keepers in the study districts

Type and shelter conditions	Mbozi N1= 138 n (%)	Mbeya rural N2=147 n (%)	Total N = 285 n (%)
Types of pig shelters			
Earthed floor	86 (62.3)	41 (27.9)	127 (44.6)
Slatted raised floor	43 (31.2)	99 (67.4)	142 (49.8)
Concrete floor	7 (5.1)	6 (4.1)	13 (4.6)
Slatted ground level floor	2 (1.5)	1 (0.7)	3 (1.1)
P value for chi square test	P < 0.001***		

Figure 12: Slatted raised floor pig shelters

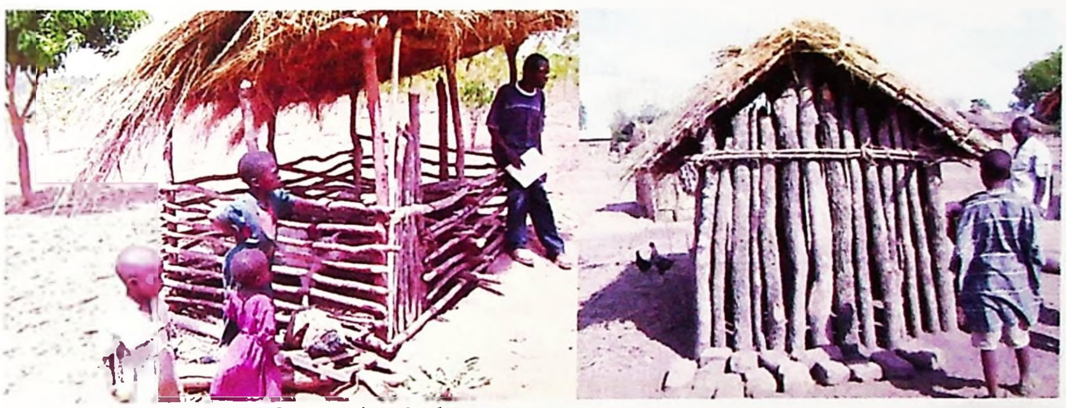

Figure 13: Earthed floor pig shelters

Figure 14: Concrete floor pig shelter

Conditions of pig shelters used by smallholder pig keepers

Conditions of pig shelters used by smallholder pig keepers are presented in Table 32. General and specific conditions of pig shelters in the visited households were assed and scored/ rated based on the general condition of pig shelter and specific condition of shelter walls. The following criteria were used:

"*Strong shelter*" = highly protective to pigs, which cannot allow the pig to get out or in the shelter freely.

"*Moderate shelter*" = protect/confine the pigs, however, minimum efforts can allow pigs out or in the shelter.

"*Weak shelter*" = weak protective to pigs whereby a pig can get in or out of the shelter when desires (Figure 16).

Figure 15: Example of weak/poor pig shelters

There was no significant ($P > 0.5$) difference between districts upon the conditions of pig shelters. Generally, only 33.1 % of pig shelters were strong enough to protect pigs form escaping from shelters. On the other hand, about 49.3 % of pig shelters were in moderate condition, while, 17.6 % of pig shelters were in weak condition.

Table 31: Conditions of pig shelters used by pig keepers in the study area

Conditions of pig shelters	Pig shelters (N = 284) n (%)
General condition of shelters	
Strong	94 (33.1)
Moderate	140 (49.3)
Weak	50 (17.6)
Wall conditions (n = 276)	
Strong	82 (29.7)
Moderate	136 (49.3)
Weak	58 (21.0)

4.1.4.4 Pig shelter in different pig management systems

Presence, types, condition, and importance of pig shelters in different pig management systems

Table 33 shows presence, types, condition, and pig keepers' perspectives on the importance of pig shelters under different smallholder management systems. All pig keepers practising TC and majority of pig keepers practising SC had pig shelters, while, significantly lower (65.4 %) proportion of pig keepers practising FRH had pig shelters ($P < 0.001$). Moreover, for those with pig shelters, types of shelters varied depending on the type of management system practised by pig keepers. Majority of pig keepers practising FRH had earthed floor type of pig shelters. On the other hand, slatted raised floor pig shelters were significantly ($P < 0.05$) more common to pig keepers practising TC management system compared to pig keepers practising SC and FRH. Concrete floor pig shelters were significantly ($P < 0.05$) higher in TC than in SC management systems. On the other hand, there was none of pig keeper practising FRH used concrete floor type of pig shelter. Among the three management systems, pig keepers practising TC had significantly ($P < 0.05$) stronger shelter condition compared to their counterparts practising SC and FRH.

Pig keepers' perspectives on the importance of pig shelters significantly varied with type of production system practised by respective pig keepers ($P < 0.001$). Significantly more pig keepers (80.3 %) practising TC viewed pig shelters as an important aspect on pig rearing compared to their counterparts practising SC and FRH, ($P < 0.05$). While, the viewpoint that pig shelters have moderate importance were higher for pig keepers practising FRH, than those practising SC and TC.

Table 32: Types, condition, and importance of pig shelters in different pig management systems

Presence, types, condition and importance of pig shelter	Management systems				P value for chi square test
	TC[2] N1= 126 n (%)	SC[3] N2 = 148 n (%)	FRH [4] N3 = 26 n (%)	Total N = 300	
Households with shelter	126 (100.0)	142 (96.0)	17 (65.4)	285 (95.0)	< 0.001***
Types of pig shelters					
Earthed floor	36 (28.6)	79 (55.6)	12 (70.6)	127 (44.6)	< 0.001***
Slatted raised floor	77 (61.1)	60 (42.3)	5 (29.4)	142 (49.8)	
Concrete floor	12 (9.5)	1 (0.7)	0 (0.0)	13 (4.6)	
Slatted ground level floor	1 (0.8)	2 (1.4)	0 (0.0)	3 (1.1)	
Shelter condition					
Strong	55 (44.0)	36 (25.4)	3 (17.7)	94 (33.1)	0.013*
Moderate	53 (42.4)	77 (54.2)	10 (58.8)	140 (49.3)	
Weak	17 (13.6)	29 (20.4)	4 (23.5)	50 (17.6)	
Viewpoint on importance of pig shelter					
Very important	98 (80.3)	89 (61.0)	10 (45.5)	197 (67.9)	0.001***
Moderately important	24 (19.7)	53 (36.3)	11 (50.0)	88 (30.3)	
Less important	0 (0.0)	4 (2.7)	1 (4.6)	5 (1.7)	

[1] Number of households, 2 total confinement, [3] semi confinement, [4] free range and/or herding

Sources and types of building materials used by pig keepers in different management systems

Table 34 shows sources of building materials for pig shelters used by pig keepers in different pig management systems. Most of building materials for pig shelters were obtained within pig keepers villages, though, under different means. About 56 % of materials were obtained free from either pig keepers farms or village, while, about 51 % were purchased in respective pig keepers villages. Very few building materials were obtained outside pig keepers' villages. Means of acquiring building materials varied between pig keepers practising different management systems. Most of pig keepers practising TC obtained their building materials through purchasing, while, majority of those practising SC and FRH obtained their building materials free.

Table 33: Sources of building materials for pig shelters used by pig keepers in different pig management systems

Sources of building materials	TC (N1 = 125) n = (%)	SC (N2 = 142) n (%)	FRH (N3 = 20) n (%)	Total (N = 287) n (%)
Free from farm	14 (11.2)	51(35.9)	8 (40.0)	73 (25.4)
Free from village	22 (17.6)	56 (39.4)	10 (50.0)	88 (30.7)
Buying within village	92 (73.6)	50 (35.2)	5 (25.0)	147 (51.2)
Free from outside village	3 (2.4)	2 (1.4)	0 (0.0)	5 (1.7)
Buying outside village	26 (20.8)	8 (5.6)	1 (5.0)	35 (12.2)

Total observation > 100 % due to multiple responses,

Timber off cuts and tree-poles/ bamboo poles were the most common building materials used by majority (94 %) of pig keepers (Table 35). Other building materials include un-burnt bricks, burnt bricks and lastly concrete bricks. Timber off cuts was most common for pig keepers practising TC. On the other hand, tree- poles and bamboo poles were most common for pig keepers practising FRH and SC management systems. About 56 % of pig shelters were roofed.

Table 34: Types of building materials used by pig keepers under different pig management systems

Wall and roofing materials	TC (N1 = 124) n (%)	SC (N2 = 140) n (%)	FRH (N3 = 17) n (%)	Total (N = 281) n (%)
Wall materials				
Timber off cuts	80 (64.5)	58 (41.4)	2 (11.8)	140 (49.8)
Tree-poles/bamboo poles	34 (27.4)	77 (55.0)	13 (76.5)	124 (44.1)
Cement bricks	1 (0.8)	0 (0.0)	0 (0.0)	1 (0.4)
Burned clay bricks	6 (4.8)	9 (6.4)	0 (0.0)	15 (5.3)
Unburned clay bricks	8 (6.5)	7 (5.0)	2 (11.8)	17 (6.0)
Roofing materials				
Households with roofed pig shelters	69 (55.2)	80 (56.3)	10 (58.8)	159 (56.0)
Thatched grass	47 (67.1)	75 (89.3)	10 (100.0)	132 (80.5)
Iron sheet	21 (30.0)	7 (8.3)	0 (0.0)	28 (17.1)
Bamboo trees	2 (2.9)	2 (2.4)	0 (0.0)	4 (2.4)
Plastic sheet	1 (1.4)	0 (0.0)	0 (0.0)	1 (0.6)
Timber off cuts	1 (1.4)	1 (1.2)	0 (0.0	2 (1.2)

Total observation > 100 % due to multiple responses,

Most (80.5 %) of pig shelters were roofed using thatched grass, while; only 17 % were roofed using iron sheets. Other roofing materials were bamboo trees, timber off cuts and plastic sheets/ materials. The use of thatch grass was relatively more common to pig keepers practising FRH and SC than TC. On the other hand, the use of iron sheets was comparatively more common for pig keepers practising TC than those practising SC and none for those practising FRH.

4.1.5 Pig feeds and feeding practices in smallholder pig production system

4.1.5.1 Main feed resources used by pig keepers

Figure 17 shows main feed resources and extent of utilization in different seasons of the year. Hominy meal was the main pig feed stuff used mostly by pig keepers with extent of feeding varying between 43.5 and 49.0 % during wet and dry periods, respectively. Other important feed resources were green forages and local brew wastes.

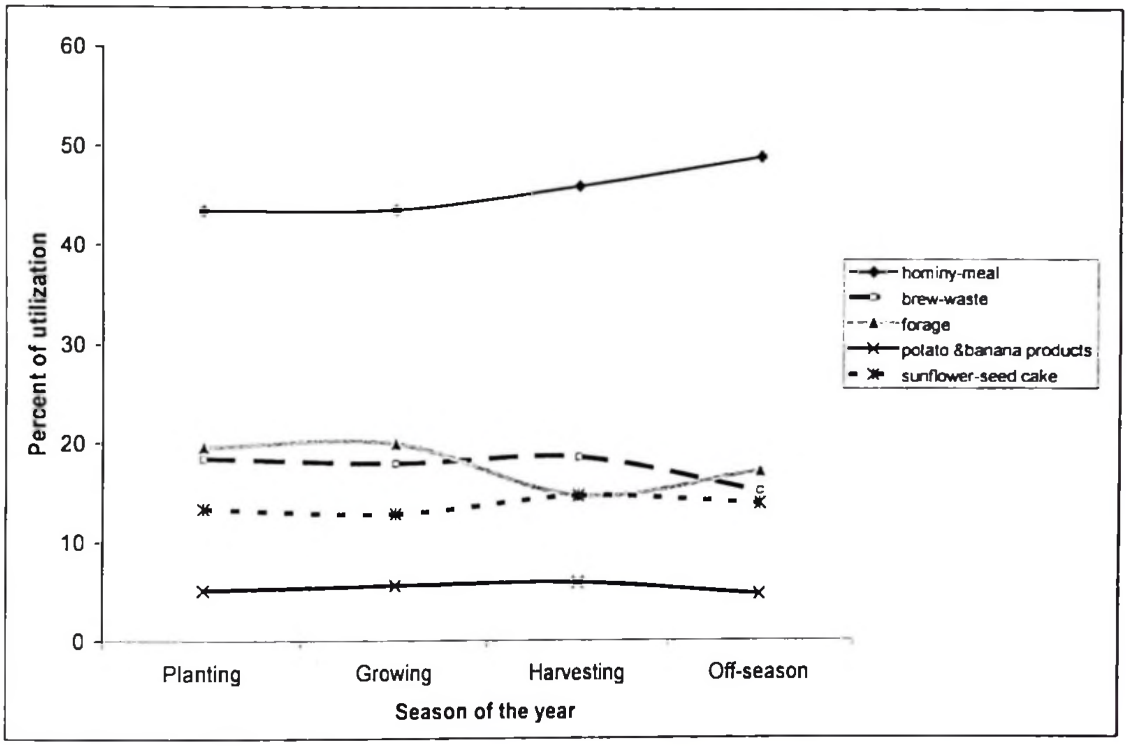

Figure 16: Main feed resources and extent of feeding in different seasons of the year

Green forages were obtained from pig keepers' and neighbouring farms, while, local brew wastes were obtained mainly from brew makers and local brew clubs/centres. Feeding of green forages was relatively higher during wet period compared to dry period, while, feeding of brew wastes was consistently similar across wet and dry seasons. Other main feed resources used by pig keepers were sunflower seed cake, potato, and banana by-products.

4.1.5.2 Types of feeding regimes and rations used by pig keepers

Pig feeding regimes and styles used by pig keepers in the study districts are presented in Table 36. Pig keepers mainly used two types of feeding regimes, either once or twice daily. Majority of pig keepers feed their pigs once daily; however, variation existed between districts. Feeding once daily was significantly common for pig keepers in Mbozi district than in Mbeya rural district ($P < 0.05$). This regime was predominantly (45.9 %) practised by pig keepers in Mbeya rural district. Feeding regimes also varied significantly ($P < 0.001$) with the seasons. During wet season, most pig keepers fed their pigs once daily. However, across the seasons once daily feeding regime was most frequent. Variation between feeding regimes within dry season was relatively low.

Type of ration used by pig keepers varied mainly with the district than seasons. Majority (76.5 %) of pig keepers used only single type feed in pig ration with Mbozi having relatively more pig keepers using it. Only 23.5 % of pig keepers used mixture of feed in pig ration, with Mbeya rural having significantly more pig keepers using these type rations ($P<0.05$). There was no variation in the use of single feeds and mixture of feeds in pig ration between wet and dry seasons ($P>0.05$).

Table 35: Pig feeding regimes and rations used by pig keepers

Districts and seasons	Feeding regime			Type of ration		
Districts	N	Once daily n (%)	Twice daily n (%)	N	Single feeds n (%)	Mixture of feeds n (%)
Mbeya rural	135	73 (54.1)	62 (45.9)	149	105 (70.5)	44 (29.5)
Mbozi	147	114 (77.6)	33 (22.4)	153	126 (82.4)	27 (17.6)
Total	282	187 (66.3)	95 (33.7)	202	131 (76.5)	71 (23.5)
P value for chi square test		< 0.001***			0.02*	
Seasons						
Wet season	138	105 (76.1)	33 (23.9)	154	124 (80.5)	30 (19.5)
Dry season	144	82 (56.9)	62 (43.1)	148	107 (72.3)	41 (27.7)
Total	282	187 (66.3)	95 (33.7)	302	231 (76.5)	71 (23.5)
P value for chi square test		P < 0.001***			0.113 NS	

4.2 Pig Keepers' Awareness, Knowledge, Experience and Risk Factors of PC

4.2.1 Importance of PC among pig health problems facing pig keepers

Table 37 shows important pig ill health problems as perceived by pig keepers using PRA matrix ranking. PC was ranked second among important pig health problems facing pig keepers in the study area. Pig keepers mainly associated PC based pig health problem with market limitations and/or losses caused by PC infection to their pigs. Pig keepers acknowledged that most of PC infected pigs did not show body deterioration, thus making the PC problem inconspicuous. Worm's infection (especially ascarids) ranked first as important pig health problem; however, the total score was very close to PC. Mange mites, other external parasites such as lice and fleas and diarrhoea were also indicated as important health problems ranking third, fourth and fifth, respectively.

Table 36: Important pig health problems as perceived by pig keepers using PRA pair wise matrix ranking

Type of ill health	Total score	Rank
Worm infection	64	1
Porcine cysticercosis	63	2
Mange mites	49	3
External parasites (i.e. lice, fleas and jiggers)	38	4
Diarhoea	20	5
Lameness	19	6
Respiratory disorders	14	7

4.2.2 Awareness and knowledge of PC by pig keepers

In this study awareness referred to possession of superficial understanding of the phenomenon, such as, being aware of PC presence and/or understanding the shape of larval stage (cyst) in pigs without deep acquaintance on mode of transmission and/or its zoonotic potential. On the other hand, knowledge referred to apparent acquaintance or understanding of the phenomenon, such as understanding the mode of transmission of PC and/or its zoonotic potential including risk of human disease like epilepsy.

Awareness of PC by pig keepers

Table 38 shows level of awareness of PC in pigs and knowledge on how pigs are infected. Majority (93 %) of pig keepers were aware of PC in pigs, with no significant ($P > 0.05$) difference between districts. Nevertheless, correct knowledge of pig keepers on how pigs get infected with PC was generally low (23.2 %). Between study districts pig keepers in Mbozi had significantly ($P<0.05$) lower (18.0 %) knowledge than their counterparts in Mbeya rural (28.6 %). Relatively large proportion (53 %) of pig keepers had no idea on how pigs get infected, while, about 24 % had erroneous knowledge (i.e.

feeding pig feed materials such as brew waste, banana leaves/suckers and/or rice polish) on how pigs get infected.

The period pig keepers got awareness of PC and trend of awareness in the study area are presented in Figure 18. The trend of awareness increased exponentially ($Y=2.049e^{0.6x}$, $R^2 = 0.98$) with increasing years. Extent of awareness was higher (43%) during last seven (2001 - 2007) years. Different ethnic groups in the study area used different names to representing cysticercus (metacestode) stage in pigs (Table 39). *Ntekenya* and *Uupemba* were the most common names used by pig keepers in Mbeya rural and Mbozi, respectively. Other names were *funza* (Mbeya rural), ***mtama*** and *Inkumba* (Mbozi).

Table 37: Level of awareness of PC in pigs and knowledge of how pig is infected

Awareness of PC in pigs	Mbozi N1= 151 n (%)	Mbeya rural N2 = 148 n (%)	Total N=299 n (%)
Aware	138 (91.4)	141 (95.3)	279 (93.3)
Not aware	13 (8.6)	7 (4.7)	20 (6.7)
P value for chi square test		0.179	
Knowledge on how pig is infected			
Correct knowledge	27 (18.0)	42 (28.6)	69 (23,2)
Incorrect knowledge	35 (23.3)	37 (25.2)	72 (24.2)
Don't know	88 (58.7)	68 (46.3)	156 (52.5)
P value for chi square test		0.05*	

Significant (P < 0.05)

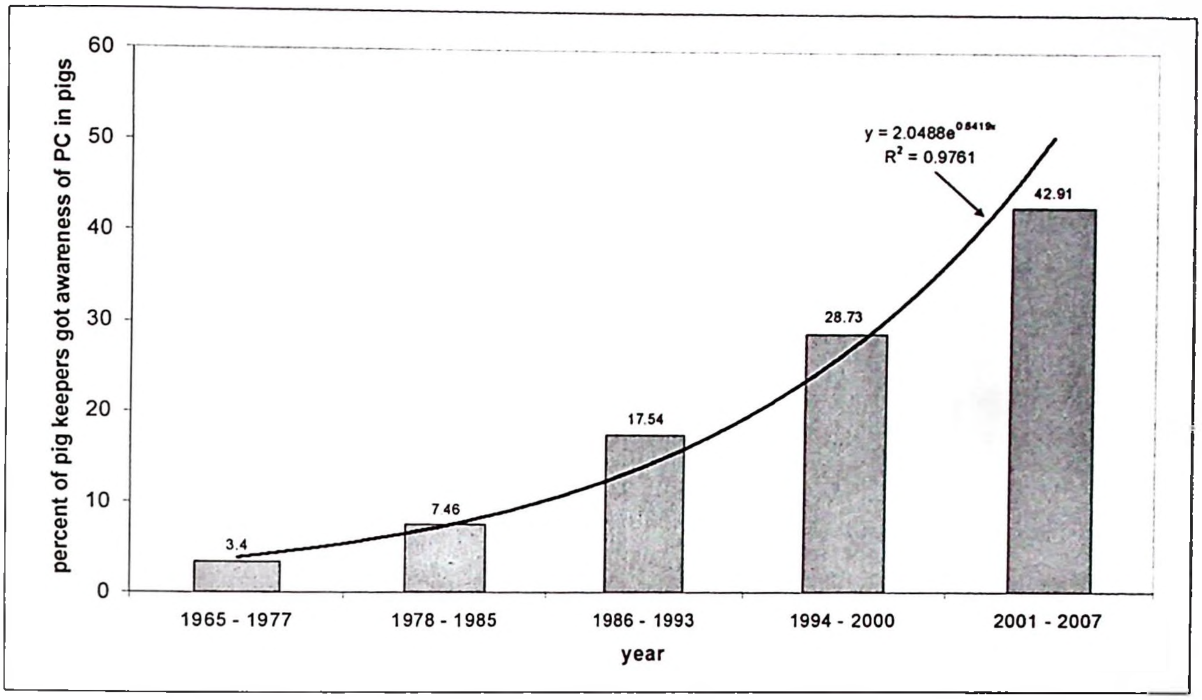

Figure 17: Period pig keepers got awareness of PC and trend of awareness in the study area

Table 38: Local names of the PC used by different ethnic groups in the study districts

Local name of the cyst	Location	Ethnic group using the name	Extent of use (%)
Ntekenya	Mbeya rural	Safwa, Wamalila, Nyakyusa	32.4
Uupemba	Mbozi	Nyiha, Ndali and Nyamwanga	27.4
Funza	Mbeya rural	Safwa, Nyakyusa, Wamalila	21.9
Mtama	Mbozi	Nyiha and Nyamwanga	10.5
Inkumba	Mbozi	Nyamwanga	7.8

4.2.2.1 The influence of different factors on the knowledge of PC by pig keepers

Table 40 shows the influence of education and districts on the status of knowledge of pig keepers on how pigs are infected with PC. Increased level of education significantly increased knowledge on how pigs were infected with PC ($P < 0.05$). Pig keepers with no formal education had significantly ($OR = 8.9$) lower knowkedge than those with secondary and primary education. Other household variables such as gender and age of households heads had no significant influence on the knowledge of pig keepers on how pigs are infected (P>0.05). On the other hand, pig keepers in Mbozi district had significantly lower knowledge than those in Mbeya rural (OR = 2.0, P<0.05)

Table 39: The influence of education and district on the status of knowledge of pig keepers on how pigs were infected with PC

Household variables and districts	N[1]	Status of knowledge (%)		Logistic regression OR (95% CI)	P-value
		Yes	No		
Education level of household head					
Secondary	21	38.1	61.9	1.0 (ref)	
Primary	221	25.8	74.2	1.9 (0.73 – 4.81)	0.19
No formal education	55	7.3	92.7	8.9 (2.29 – 34.94)	0.002**
Total	297	23.2	76.8		
Study districts					
Mbeya rural	147	28.6	71.4	1.0 (ref)	
Mbozi	150	18.0	82.0	2.0 (1.14 – 3.53)	0.015*
Total	297	23.2	76.8		

[1]Number of households, * significant (P< 0.05), ** significant (P < 0.01)

4.2.2.3 Awareness and knowledge of pig keepers on relationship between cysticercosis in pigs and taeniosis in human beings

Table 41 shows the influence of education on the awareness and knowledge of pig keepers on relationship of PC infected pig/pork and wellbeing of humans. Pig keepers' awareness that the infected pig/pork can affect humans increased with increased level of education, however, the difference was not statistically (P>0.05) significant. On the other hand knowledge of pig keepers on how infected pork affect humans was significantly (P<0.05) higher for pig keepers with primary and secondary education than their counterparts with informal education.

Table 40: Influence of education on awareness and knowledge of pig keepers on association of PC infected pig/pork and health of human being

Education level of household head	N	Aware that the PC infected pig/pork can affect human N1= 138 n (%)	Knowledgeable on how PC infected pork affect human N2 = 82 n (%)
No formal education	55	8 (14.6)	4 (7.3)
Primary education	220	55 (25.0)	31 (14.1)
Secondary 0-level	20	6 (30.0)	6 (30.0)
Total	295	69 (23.4)	41 (13.9)
P value for chi square test		0.201	0.042 *

4.2.3 Experiences of pig keepers on PC infection and existing coping strategies

Table 42 shows pig keepers experience of PC infection in their pig herd. Experiences of PC in pig keepers pig herds varied significantly ($P<0.05$) between districts. Considerable proportions (21.6 %) of pig keepers have experienced PC infection in their herd. According to pig keepers PC experience, pig traders identified most PC infected pigs during the process of pig marketing through lingual examination. Different PC experiences had the influence on the decisions of pig keepers on how to deal with PC infected pig(s) (Table 43). High proportion (54 %) of pig keepers with previous PC experience in their herd would sell their PC infected pigs with or without treatment compared to their counterpart who have never experienced and those not aware on the status of PC in their herd. Most pig keepers with no awareness of, or never experienced PC in their pig herd showed lack of any immediate decision if their pigs were discovered PC infected. Advice from extension officers was among the relatively important option expressed by 18 % of pig keepers if they discover that their pigs are PC infected. In this situation, pig keepers with no PC experience showed more reliance on advice from extension officers, followed by those with PC experience and lastly those with no awareness.

Table 41: Pig keepers' experience of PC infection in their pig herd

District	Number of household N	PC experience in own herd			P value for chi square test
		Experienced n (%)	Never experienced n (%)	Not aware n (%)	
Mbozi	148	31 (21.0)	96 (64.9)	21 (14.2)	0.021*
Mbeya	148	33 (22.3)	108 (73.0)	7 (5.0)	
Total	296	64 (21.6)	204 (68.9)	28 (9.5)	

* Significant (P < 0.05)

Table 42: Responses of pig keepers on anticipated decision if discovering their pigs are PC infected based on previous personal experience with PC

Coping strategy	Farmer's experience with PC in the herd			Total
	Yes N1 = 62 n (%)	No N2 = 195 n (%)	Not aware N3 = 27 n (%)	N = 284 n (%)
Don't know	8 (12.9)	69 (35.4)	18 (66.7)	95 (33.5)
Sell the pig after treatment	12 (19.4)	48 (24.6)	2 (7.4)	62 (21.8)
Sell the pig	22 (35.5)	21 (10.8)	3 (11.1)	46 (16.2)
Seek advice from extension personnel	9 (14.5)	41 (21.0)	2 (7.4)	52 (18.3)
Condemn it	1 (1.6)	8 (4.1)	1 (3.7)	10 (3.5)
Use for breeding	4 (6.5)	5 (2.6)	0	9 (3.2)
Slaughter at home	2 (3.5)	3 (1.5)	1 (3.7)	6 (2.1)
Barter with other items	4 (6.5)	0.0	0.0	4 (1.4)

4.2.4 Home pig slaughter, inspection, and pork utilization by pig keepers

4.2.4.1 Extent of home pigs slaughter by smallholder pig keepers

Table 44 shows proportion of pig keepers practiced home pig slaughter from January and November 2007 in the study districts. Only about 18 % of pig keepers' households slaughtered pigs at home with mean frequency of 3.6 ± 10.5 times per year. Extent of home slaughtered pigs was significantly higher (25.5 %) for pig keepers in Mbozi district ($P < 0.001$). Table 45 presents how pork slaughtered at home ascertained safe for human consumption among households' practised home slaughter of pigs. Comparatively few pig keepers performed home slaughter used official meat inspector to inspect pig carcasses. Most (53. 8 %) of pig keepers used traditional inspection methods to ascertain the safety of pork for human consumption.

Table 43: Pig keepers slaughtered pigs at home from January to November 2007

Home slaughter	Mbozi N1 = 149 n (%)	Mbeya-rural N2 =147 n (%)	Total N = 296 n (%)	Frequency of slaughter per year Mean ± s.d
Yes	38 (25.5)	14 (9.5)	52 (17.6)	3.6 ± 10.5
No	111 (74.5)	133 (90.5)	244 (82.4)	
P value for chi square test		< 0.001***		

Traditional safety measures indicated by pig keepers includes an overview of general look of carcass, and if suspicious, a small piece of meat would be tested by giving it to a cat, if a cat accepted it then the meat would be declared safe for human, if refused then it is declared not safe for human. Similarly, relatively few (3.8 %) of pig keepers relied on the background history (i.e. sickness) of slaughtered pigs. On the other hand, about 31 % of pig keepers did not take any consideration to ascertain their slaughtered pigs were safe for human consumption.

Table 44: How pork slaughtered at home was ascertained safe for human consumption among farmers practised home slaughter

Safety assurance at home slaughtered pig	Number of households N = 52 n (%)
Using traditional inspection methods	28 (53.8)
Not any considerations made	16 (30.8)
Observing background of slaughtered pig	2 (3.8)
Using official meat inspector [1]	5 (9.6)
Using medical practitioner	1 (1.9)
Total	52 (100.0)

[1] Meat inspectors recognised by government authority responsible for meat inspection in the defined location

4.2.5 Risk factors for PC in smallholder pig keepers households

4.2.5.1 Household level PC prevalence and effect of socio-economic factors on the household (HH) PC prevalence

Prevalence's of PC (using Ag-ELISA) in pig keepers' households in the respective study villages are shown in Appendix 9 and 10 for Mbeya rural and Mbozi districts, respectively. In this study, a household was considered PC prevalence positive when at least one pig in the household was found infected using Ag-ELISA. The results of Ag-ELISA showed that all study villages were PC infected, however, the extent of infection varied between villages. In villages of Mbeya rural district, the proportion of PC infected households ranged between 10 and 90 %, and about 47 % of them had more than 49 % of their households infected (Appendix 9). In the study villages of Mbozi district, the proportion of PC infected households also ranged between 10 and 90 %, and about 53 % of villages had more than 49 % of their household infected (Appendix 10). Mean PC positive households were generally high (45.3 %) in both districts, moreover, there was no significant difference between districts (P > 0.05)

(Table 45). Similarly, households' socio-economic factors such as marital status, education level, gender, and age of household head had no significant (P > 0.05) effects on PC prevalence in the households (Table 46).

Table 45: PC prevalence in pig keepers households' in Mbozi and Mbeya rural districts

District	Number of households	PC positive households (%)	Odd ratio	95% CI	P - value
Mbozi	151	45.7	1.0 (ref)		
Mbeya	149	44.0	0.97	0.62 - 1.53	0.899
Total	300	45.3			

Table 46: The effect of households' socio-economic factors on pigs PC prevalence in the household using multiple logistic regressions (MLR)

	Level	N[1]	PC positive households (%)	Odds ratio	95% CI	P-value
Marital status	Married	256	45.7	1.0 (ref)		
	Non-married	44	43.2	0.92	0.12–7.38	0.93
Education	Secondary	21	33.3	1.0 (ref)		
	Non-formal	55	43.6	1.73	0.57 - 5.28	0.33
	Primary	224	46.9	1.81	0.70 - 4.66	0.22
Gender of HH head	Man	256	45.7	1.0 (ref)		
	Women	44	43.2	0.91	0.12 - 7.15	0.93
Age group (yr)	18 – 37	125	45.6	1.0 (ref)		
	38 – 57	136	47.1	1.08	0.66- 1.78	0.76
	57 - 90	37	37.7	0.74	0.33 - 1.69	0.48

[1] number of households

4.2.5.2 The effects of pig management systems and practices on prevalence of PC in smallholder pig keeper's households

Table 47 shows the effects of selected factors related to household management systems and practices on prevalence of PC using MLR. PC prevalences were significantly (OR = 2.1, $P < 0.01$) higher in both households practicing SC and FRH management systems than their counterparts practising TC. Types of pig shelter was an important risk factor for PC transmission. PC prevalence was significantly (OR = 8.4, $P < 0.05$) higher for households with slatted raised floor than households with earthed floor and concrete floors. On the other hand, general conditions of pig shelter, wall, and floor of pig shelters had no significant effects on PC prevalence ($P > 0.05$).

Table 47: The effects of selected factors related to household management systems and practices (pig shelters) on prevalence of PC using MLR

	Level	N[1]	PC positive households (%)	Odds ratio	95% CI	P-value
Management system	TC	126	35.7	1.0 (ref)		
	SC and FRH	174	52.3	2.1	1.25 – 3.64	0.006**
Types of pig shelter	Concrete	13	7.7	1.0 (ref)		
	Earthed	130	46.7	6.7	0.79 – 58.07	0.082
	Slatted	142	48.6	8.4	1.01 – 69.96	0.049*
Condition of pig shelter	Strong	94	43.6	1.0 (ref)		
	Weak	190	46.3	0.8	0.27 - 2.63	0.77
Wall condition	Strong	82	39.0	1.0 (ref)		
	Weak	195	48.7	1.9	0.81 – 4.48	0.138
Floor condition	Strong	84	44.1	1.0 (ref)		
	Weak	200	46.0	0.6	0.19 – 1.61	0.28

[1] Number of households, * Significant ($P < 0.05$), ** significant ($P < 0.01$)

4.2.5.3 Effects of awareness and knowledge, pig keeping experience and past experience of PC in the pig herd on prevalence of PC in the household

Table 48 shows the effects of past experience of PC in the pig herd of pig keepers on the PC prevalence in their households. Past experience of PC in the pig herd was a significant risk factor (OR = 2.6, P< 0.01), however, experience in pig keeping had no significant effect on PC prevalence in the household (P>0.05). On the other hand, different levels of awareness and knowledge of pig keepers on PC were not significant risk factors on the PC prevalence (P> 0.05).

Table 48: The effects past experience of PC in the herd on PC prevalence in their households

Factor	Level	N[1]	PC positive households (%)	Odd ratio	95% CI	P-value
Past experience of PC in the pig herd	No	204	39.7	1.0 (ref)		
	Yes	64	62.5	2.6	1.446 - 4.832	0.002**
	Don't know	28	42.9	1.2	0.542 - 2.754	0.630

[1] Number of households, ** Significant (P < 0.01)

4.2.5.4 The effects of hygienic factors: presence and condition of latrines, sources and distance to water sources on PC prevalence in the households

Table 49 presents the effects of presence and condition of latrines in the households of pig keepers on the prevalence of PC in their households using MLR. Presence or absence of latrine and conditions of latrine had no significant effects on PC prevalence in the household (P > 0.05). Effects of different sources of water in the households and distance to water sources on prevalence of PC are shown in Table 50. Water sources in the pig keepers' households were important risk factors for PC transmission. PC prevalence was significantly higher for pig keepers sourcing water from rivers than their counterparts from tape water, borehole and springs (OR = 3.1, P < 0.001).

Similarly, water from ponds was a significant risk factor for PC transmission than water from tape water (OR = 5.0, P < 0.05). Distance to water sources had no significant effects on PC prevalence in pig keepers household (P > 0.05).

Table 49: Effects of presence and conditions of latrines in the households on the prevalence of PC in the households of pig keepers using MLR

Factors	Level	N[1]	PC positive households (%)	Odds ratio	95% CI	P-value
Presence of latrine	Yes	281	44.5	1.0 (ref)		
	No	18	61.1	1.96	0.74 - 5.21	0.176
Condition of latrine walls	Strong	234	42.3	1.0 (ref)		
	Poor or incomplete	49	55.1	1.65	0.88 - 3.13	0.121
Presence of human faeces around latrine/homestead	No	225	44.4	1.0 (ref)		
	Yes	57	43.9	0.89	0.49 - 1.62	0.696

[1] Number of households

Table 50: Effects of different sources of water and distance to water sources on prevalence of PC using MLR

Factors	Level	N[1]	PC positive households (%)	Odds ratio	95% CI	P-value
Sources of water	Tape water	61	32.8	1.0 (ref)		
	Borehole	100	40.0	1.6	0.80 - 3.16	0.185
	Spring	28	35.7	1.2	0.44 - 3.24	0.725
	River	98	60.2	3.1	1.56 - 6.30	< 0.001***
	Ponds	11	63.6	5.0	1.16 - 21.70	0.031*
Distance to water source (m)	201 – 800	98	38.8	1.0 (ref)		
	< 200	80	48.7	1.6	0.86 - 3.0	0.141
	> 800	104	53.8	1.6	0.87 - 2.79	0.139

[1] Number of households, * Significant (P < 0.05), *** significant (P < 0.001)

4.3 Smallholder Pig Marketing Systems

4.3.1 Market channels for pigs and pork in smallholder pig marketing system

Figure 19 shows market channels for pigs and pork in smallholder pig marketing system. Marketing channels facilitate the flow of goods from producers to consumers. Smallholder pig marketing system involved mainly three groups of market participants. The first group include pig keepers as main pig producers and to some extent, as important pig buyer as well as pork consumers. The second group involved pig traders, consisting mainly six types of pig traders; butchers, retailers, pig collecting agents (PCA), pork processors (PP), pork centre operators (PCO) and pig transporters (PT). The third and last group was mainly pork consumers. The marketing chain for pigs varied from short chain (i.e. producer to consumer at same village level) to longer chain (from village to urban/city level).

4.3.1.1 Pig keepers

Pig keepers were the first link in the pig market chain. Pig keepers normally sold their pigs depending on different circumstances, which necessitated the need for income. Mainly two types of bargaining scenarios existed depending on who is buying the pig between pig keepers and pig traders. In most cases, pigs purchased by pig keepers were normally booked by respective buyers, who may at times make advance payments. On the other hand, for pigs bought by pig traders, normally pig keepers will inform local pig traders of their intention to sell the pig(s). Thereafter, the transaction involved instant bargaining and purchasing of pigs, normally taking place in the pig keepers' households. About 75 % of pig keepers sold their pigs to pig traders, while, about 30 % of pig keepers sold their pigs to other fellow pig keepers (Fig. 19).

4.3.1.2 Pig traders

Butchers were among the important pig traders buying about 78 % of live pigs from pig keepers. They were also purchasing some pigs from other intermediate traders, such as pig retailer (19 %) and PCA (3 %) (Fig. 19). After purchasing pigs from pig keepers, the pigs were transported using different methods depending on the proximity to butchers dwellings. For close proximities trekking was the most used method, while, for far distances the use of car and/or bicycle was very common. Thereafter, most of pigs were slaughtered and sold direct to consumers or to intermediaries' traders such as PP and PCO. Most of butchers were situated in urban areas

Pig retailers were usually the intermediate pig traders purchasing pigs mainly (100 %) from pig keepers and sell them to other pig traders such as butchers, PCO and PT (Fig. 19). Pig retailers were normally few in number with relatively high volumes of trade, and operated mainly in Mbeya rural district. PCA were also intermediate pig traders buying pigs mostly (100 %) from pig keepers on behalf of PT and butcher.

Pork processors (PP) were the pig traders mainly dealing with pork processing in urban areas. PP normally purchased most (76 %) of their product (fresh pork) from butchers, and other fellow PP (14%), while, few of them purchased live pigs (10 %) from pig keepers (Fig. 19). After being processed, the products (roasted/fried, boiled pork, barbeques etc.) were sold to instant pork consumers and/or domestic consumers. However, some amount of pork was also sold fresh for domestic consumption.

PCO were the pig traders dealing with live pigs and pork located mainly in rural areas. PCO mainly purchased live pigs mostly (76 %) from pig keepers. However, 13 % purchased live pigs from retailers and sometimes pork from butchers (Fig 19). Most of pigs purchased by PCO were slaughtered and sold fresh or processed to consumers mainly in local brew bars, market place or in streets. Pig transporters (PT) were among the pig traders buying relatively large number of live pigs and transport them to other regions especially to Dar-es-salaam. PT purchased pigs from different sources such as pig keepers (41 %), retailers (29 %) and PCA (30 %).

4.3.1.3 Pork consumers

Pork consumers were the last link in the pig marketing chain, whereby, pig keepers were among the prominent pork consumers. Pork was either purchased fresh or processed from different pig traders depending on the locality and preference of consumers

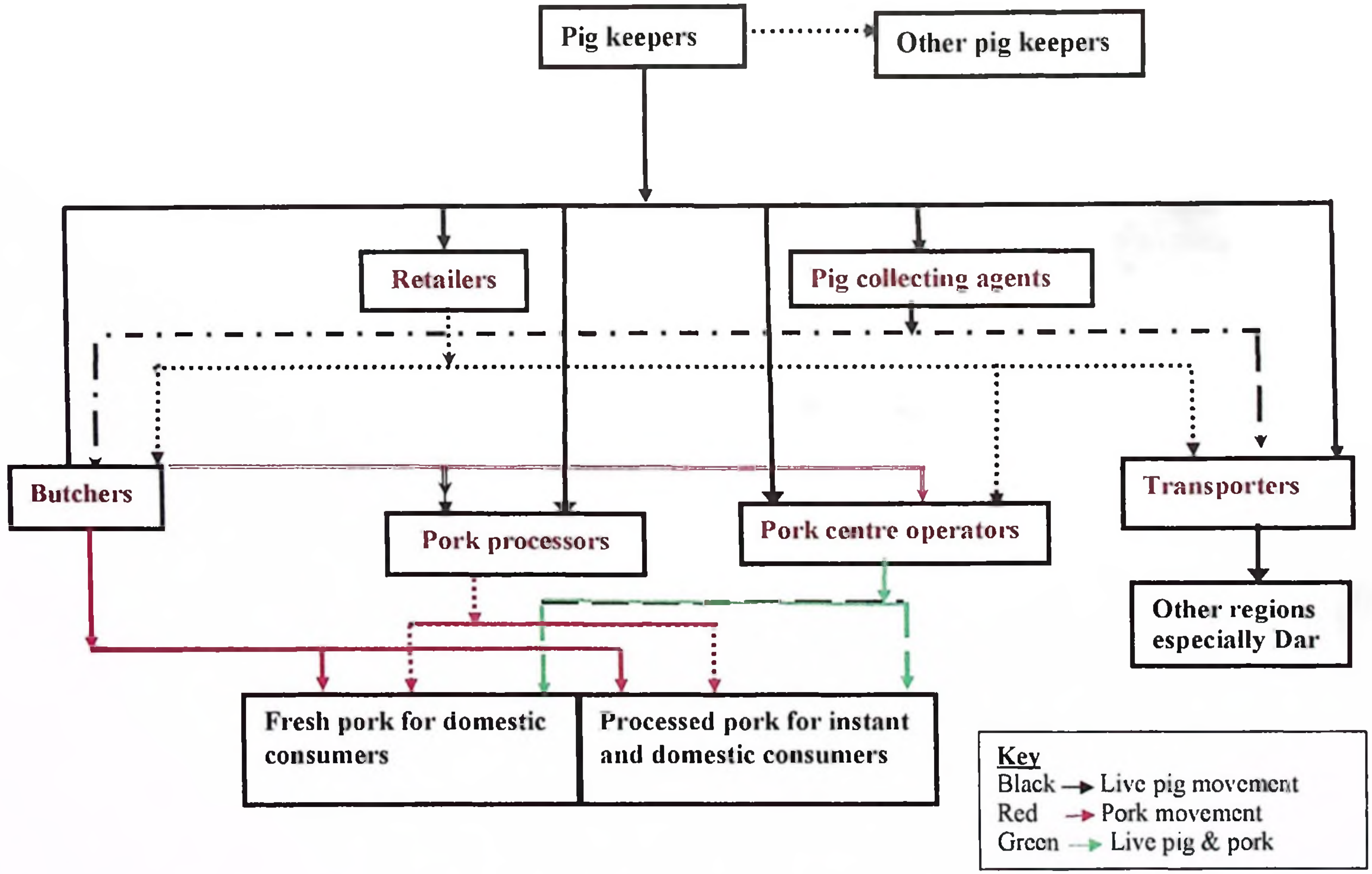

Figure 18: Market channels for pig and pork in smallholder pig marketing system

4.3.2 Pig marketing chain characteristics at producers' level

4.3.2.1 Pig acquisition and price characteristics by pig keepers

Pig acquisition characteristics

Table 52 shows extent of pig acquisition, location of acquisition, sources of pigs, place of exchange and purpose of pig acquisition by pig keepers from January to November 2007. There were no significant differences in pig acquisition in terms of location of acquisition, sources of pigs, place of exchange, purpose of acquisition, and means of acquisition between study districts ($P < 0.05$). Majority of pig keepers acquired their pigs mainly from other pig keepers within their villages. Relatively few (26.7 %) pig keepers acquired their pigs from neighbouring villages and very few from far villages, other districts and other region. Contrary to other types of livestock such as cattle, goats and sheep where the main place of exchange are in market places (i.e. in primary markets), for pigs, main places for exchange were in pig keepers' households. The main reason for pig acquisition by pig keepers was for breeding, followed by fattening and very few for slaughtering purposes. Means of acquisition was mainly through buying, and very few by hiring in and gift.

Table 51: Extent of pig acquisition, location, source, place of exchange and purpose of pig acquisition

Pig acquisition variable	Number of households n (%)
Pig keepers acquired pigs during 2007 (N1 =299)	135 (45.2)
Location where pigs were acquired (N2 = 135)	
Within the village	91 (67.4)
Neighbouring villages	36 (26.7)
Far villages	16 (11.9)
Other districts within region	1 (1.5)
Other (neighbour) region	2 (0.7)
Sources of live pigs (N2 = 135)	
Other pig keepers	131 (97.0)
Pig traders	1 (1.5)
Institutes	2 (1.5)
Place of exchange (N2 = 135)	
Pig keepers household	133 (98.5)
Market place	2 (1.5)
Purpose of pig acquisition (N2 = 135)	
Breeding	115 (85.2)
Fattening	24 (17.8)
Slaughtering	2 (1.5)
Means of pig acquisition (N = 135)	
Purchase	124 (91.9)
Gift	6 (4.4)
Hire [1]	5 (3.7)

[1] Acquiring a female(s) pig mainly for breeding purpose from another pig keeper under specific arrangement, such as sharing the offspring when a sow farrowed

Age, weight, and price characteristics for pigs bought by pig keepers

Price paid for pigs of different ages and live weights purchased by pig keepers in the 40 monitored households from January – August 2008 are shown in Table 53. Higher (53.6 %) proportion of pigs purchased were in weaning (2 – 3 months) to growing (3.1 – 5 months) stages. Relatively few of pigs purchased by pig keepers were in ages above eight months. Generally purchasing price for pigs increased with age. However, the extent of increase varied considerably between different age groups (Table 53 and Fig. 20). When the relationship of age and price was considered into univariate analysis (Fig. 20) regression coefficient (β = 841.24) denoting the change in price per unit change in age was high. However, the model could explain only 22 % (R^2) of variation between price and age. When specific weight and age were considered together into multivariate analysis (Table 53), correlation between age groups and pig prices were positive at pig ages between 2 and 5 months, however, price variation between these weight groups was not statistically different ($P > 0.05$). Regression coefficients between pig age groups above 5 months and pig prices were negative denoting the tendency of decreasing price with increased age, however, variation existed between age groups (Table 53). Correlation coefficients between age groups and price were significantly ($P < 0.001$, β = -17706.6) the lowest for pigs at ages above 12 to 16 months, followed by pig with ages above 8 to 12 months ($P < 0.05$, β = -8140.2)

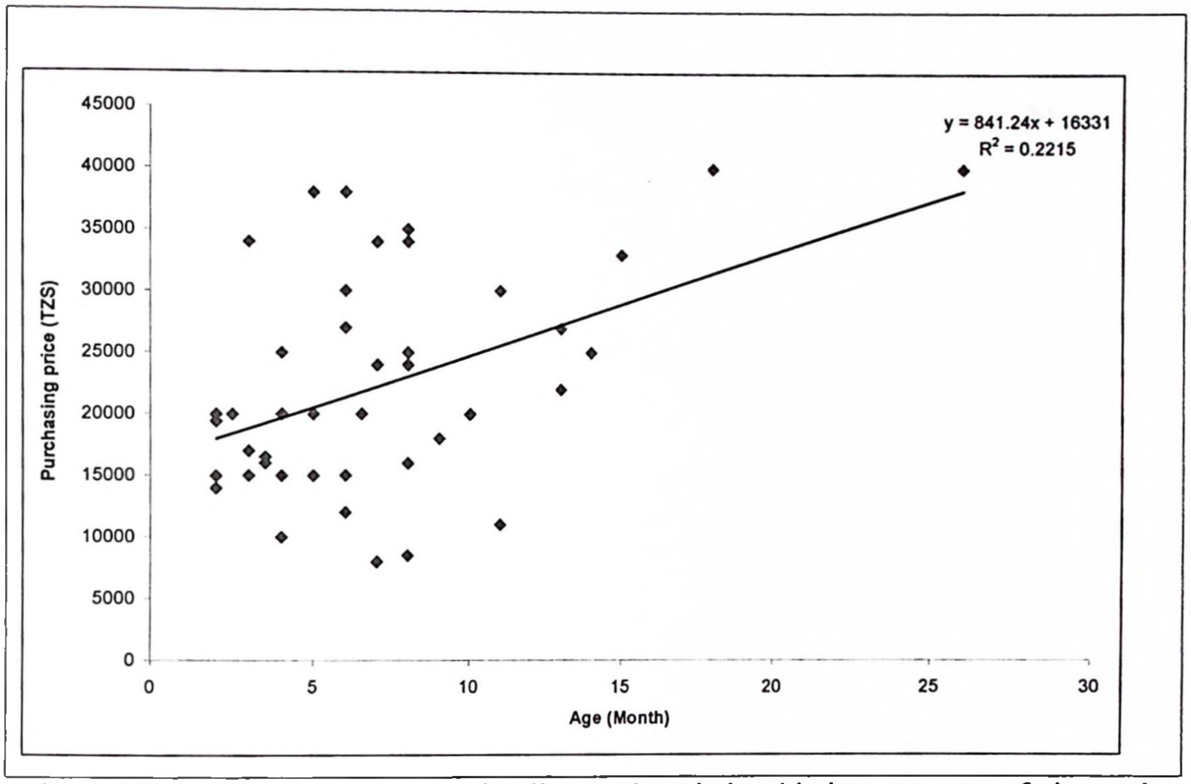

Figure 19: Scatter plot and regression line on the relationship between age of pigs and purchasing price for pigs bought by pig keepers

Most (70.4 %) of the pigs purchased by pig keepers weighed between 7 and 20 kg live body weight (Table 53). Purchasing price of live pigs increased with increased pig weight, however, variations also existed between specific weight groups. When relationship between pig weights and prices was measured by univariate analysis (Fig. 21) coefficient of regression denoting the variation of price per unit change in weight was 477.89 with moderately high coefficient of determination ($R^2 = 0.59$) showing the model could explain about 59 % of variations. When relationship between age and weight with price was considered together using partial correlation (Table 54) and multiple regressions between specific pig weights and ages (Table 53), general and specific variations between age and weight with prices were observed. Generally the increased live weights was significantly positively correlated with increased purchasing price ($r = 0.74$, $P < 0.001$). Among different weight groups of pigs, purchasing price for pigs weighing between 10 and 15 kg live body weight were not statistically different from pigs with weight between 7 and 10 kg (P > 0.05). However, prices for different pigs' weight groups exceeding 15 kg live body weight were consistently and significantly positively correlated with body weight (P < 0.05, 0.001).

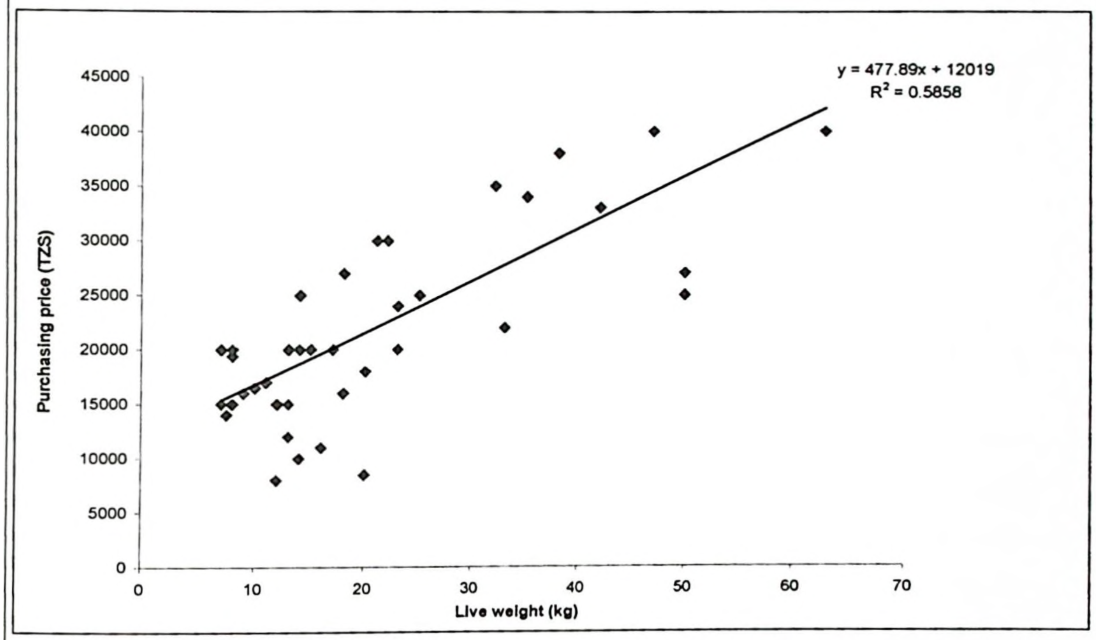

Figure 20: Scatter plot and regression line on relationship between live weight (kg) and purchasing price (TZS) of pigs bought by pig keepers

Table 52: Price for different ages and weights and its relationship to specific weight and age groups of pigs purchased by pig keepers from January to August 2008

Age and weight of purchase pigs	N[1] (%)	Mean price per live pig (mean ± s.d.)	Regression Coefficient (β)	P value and significance	95 % Conf. Interval
Age group (months)					
2 - 3	23 (33.3)	17 900±4,689	Ref[2]		
3.1 - 5	14 (20.3)	20 050±7,833	228.9	0.915	-4 050.6 - 4508.4
5.1 - 8	18 (26.1)	23 972.2 ± 9104.7	-4940.5	0.068	-10 268.0 - 387.1
8.1 - 12	5 (7.3)	18 000.0 ± 7842.2	-8140.2	0.021*	-15 007.7 - -1272.5
12.1 - 16	6 (8.7)	26 750.0 ± 4645.8	-17706.6	< 0.001***	-28 207.1 - -7206.0
16.1 - 26	3 (4.4)	40 000.0 ± 0.0	-6040.0	0.356	-19 109.0 - 7029.1
Weight group (kg)					
7 – 10	22 (34.4)	16 580.0 ± 2328.2	Ref[2]		
10.1 – 15	14 (21.9)	17 000.0 ± 5639.1	1 714.7	0.394	-2 306.8 - 5736.2
15.1 – 20	9 (14.1)	17 312.5 ± 7116.1	6 257.2	0.045*	137.4 - 12377.0
20.1 – 25	8 (12.5)	25 285.7 ± 3592.3	14 590.9	< 0.001***	8 170.4 - 21011.3
25.1 – 30	6 (9.4)	33 500 ± 5924.5	23 157.1	< 0.001***	16 910.9 - 29403.3
30.1 – 63	5 (7.8)	33 000.0 ± 7035.6	29 490.5	< 0.001***	17 833.6 - 41147.2
Constant			16 549.5	< 0.001***	14 275.9 - 18823.0

[1] Number of pigs, * P < 0.05, ** P< 0.01, *** P< 0.001, [2] = Reference category

Table 53: Partial correlation between price (TZS) and age (months) and weight (kg) of pigs purchased by pig keepers

Variable	Correlation	P-value and Significance
Pig weight (kg)	0.7425	<0.001 ***
Pig age (month)	-0.4392	0.001 ***

• P < 0.05, ** P< 0.01, *** P< 0.001,

4.3.2.2 Determinants of selecting pigs to purchase and price used by pig keepers during the process of buying pigs

Determinants of selecting pigs to purchase used by pig keepers during the process of buying pigs are shown in Table 55. Pig body size was the most important pig determinant used by pig keepers in choosing pig to buy and price to pay, nevertheless, variation existed between study districts. This criterion was significantly more common for pig keepers in Mbozi district than in Mbeya rural district (P < 0.001). Notably, there were no specific weighing scales to measure live body weight of pigs during marketing processes; however, some pig keepers said they were able to use their experience to estimate weights of intended pigs. Examination of a pig either PC infected or not was ranked second amongst the important criteria for buying pigs. This criterion was also more (40.4 %) used by pig keepers in Mbozi district than their counterparts (15.3 %) in Mbeya rural (P < 0.001). External healthy appearance was ranked third and was equally used in both districts (P>0.05). Pig body length, which ranked fourth, and it was significantly more used by pig keepers in Mbozi than in Mbeya rural district (P < 0.01). Pig keepers said they preferred pigs with long bodies than shorter ones. Other criteria include performance background (performance history of the herd and/or parents of intended pig) and coat colour. Most pig keepers said they preferred white coat colour to other colours.

Table 54: Determinants used by pig keepers for selecting pigs to purchase during the process of buying pigs

Examination criteria	Proportion of pig keepers using the criterion			Districts differences: Chi square test	Score [1]	Overall rank
	Mbozi N1 = 151 n (%)	Mbeya rural N2 = 149 n (%)	Total N = 300 n (%)			
Body size	108 (71.5)	55 (36.9)	163 (54.3)	0.001***	497	1
PC[2]	61 (40.4)	22 (15.3)	83 (28.1)	<0.001***	295	2
Healthy looking	35 (23.2)	22 (14.8)	57 (19.0)	0.063 NS	146	3
Body length	33 (21.8)	15 (10.1)	48 (16.0)	0.005**	138	4
Performance background	16 (10.6)	25 (16.8)	41(13.7)	0.119 NS	116	5
Coat colour	21(13.9)	4 (2.7)	25 (8.3)	0.001***	47	6

[1] Score calculated as cumulative cross product of frequency and rank weight given to each criterion by each respondent in the cross-sectional study, [2] Lingual palpation/inspection, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$,

Main determinants of price for pigs purchased by pig keepers are given in Table 56. Among the determinants of selecting pigs to purchase such as body size, healthy looking, body length and coat colour were shown as important purchasing price determinants. In this regard, pig body size (weight) ranked first among important price determinants. Pig breed was ranked second. According to experience from pig keepers, exotic pig breed of same age and weight was purchased at higher price than indigenous one. Sex of the pigs ranked third which was more used by pig keepers in Mbozi district than in Mbeya rural ($P < 0.001$). Female pigs were sold at higher prices than males. Healthy appearance was ranked fourth as a price determinant. Consequently, healthy pigs were sold at higher price than unhealthy ones. Pig body length as price determinant ranked fifth with no significant ($P > 0.05$) difference between the two districts. Seasons (wet and dry) of the year and fatty status of the pig were ranked sixth and seventh respectively as price determinants. According to pig keepers, pig prices were higher during the dry than the wet season. Although fatty status of pigs was closely linked to weight, pig keepers showed specific interest on fatty status of pig(s) as important price determinant, which ranked seventh among price determinants. Fatty pigs were sold at higher prices than thinner ones. Most villages use lard from pork as cooking oil, thus making lard an important item. Other price determinants were the pig coat colour and location where the pig was bought which ranked eighth and ninth, respectively. Pigs with white coat colour (dressing easy) were more preferred with relatively higher price. On the other hand, pigs bought in more remote villages' fetched lower prices than similar pigs bought near or in urban areas.

Table 55: Main purchasing price determinants for pigs purchased by pig keepers

Price determinant	Proportion of pig keepers using the determinant			Districts difference: P- value for chi square test	Score [1]	Rank
	Mbozi N1 = 151 n(%)	Mbeya rural N2 = 149 n (%)	Total N = 300 n (%)			
Body size	101 (66.9)	52 (34.9)	153 (51.0)	< 0.001***	445	1
Breed	57 (37.8)	42 (28.2)	99 (33.0)	0.078	264	2
Sex	65 (43.1)	10 (6.7)	75 (25.0)	0.001***	176	3
Healthy looking	53 (35.1)	21 (14.1)	74 (24.7)	< 0.001***	157	4
Body length	25 (16.6)	16 (10.7)	41 (13.7)	0.142	79	5
Season of the year	43 (28.5)	19 (12.7)	62 (20.7)	0.001***	76	6
Fatty status	16 (10.6)	2 (1.3)	18 (6.0)	0.001***	27	7
Coat colour	11 (7.3)	2 (1.3)	13 (4.3)	0.011*	24	8
Location where pig is bought	2 (1.3)	1 (0.7)	3 (1)	0.57	4	9

[1] Score calculated as cumulative cross product of frequency and rank weight given by each respondent in the cross-sectional study, * P < 0.05, ** P< 0.01, *** P< 0.001,

4.3.2.3 Pig disposal and off take characteristics of smallholder pig keepers

4.3.2.4 Locations where pig keepers sold their pigs and their main customers

Pig keepers' customers of live pigs by location and type are shown in Table 57. Majority (80.5 %) of pig keepers sold their pigs within their villages to customers mostly from within and neighbouring villages. Only a few pig keepers sold their pigs outside their villages, such as, neighbouring villages, far villages, other districts, and neighbouring countries (mainly Zambia). Majority (75 %) of pig keepers sold their pigs to pig traders, while, 30 % of them sold their pigs to other pig keepers. There were no significant differences between the two study districts on location and main customers of pigs sold by pig keepers ($P > 0.05$). Seasonal trends in pig disposal varied across wet and dry seasons (Fig. 22). During the wet season, the extent of pig disposal decreased consistently from January to mid April reaching the lowest off-take at the end of April, thereafter, increased consistently.

Table 56: Location where pig keepers sold their pigs and main customers

Location and customers of pigs	(N = 185) n (%)*
Locations	
Within village	149 (81)
Neighbouring village	28 (15)
Far village	11 (6)
Other districts	2 (1)
Neighbour country	4 (2)
Types of customers	
Other pig keepers	56 (30)
Pig traders	133 (75)

* Total observation > 100 % due to multiple response

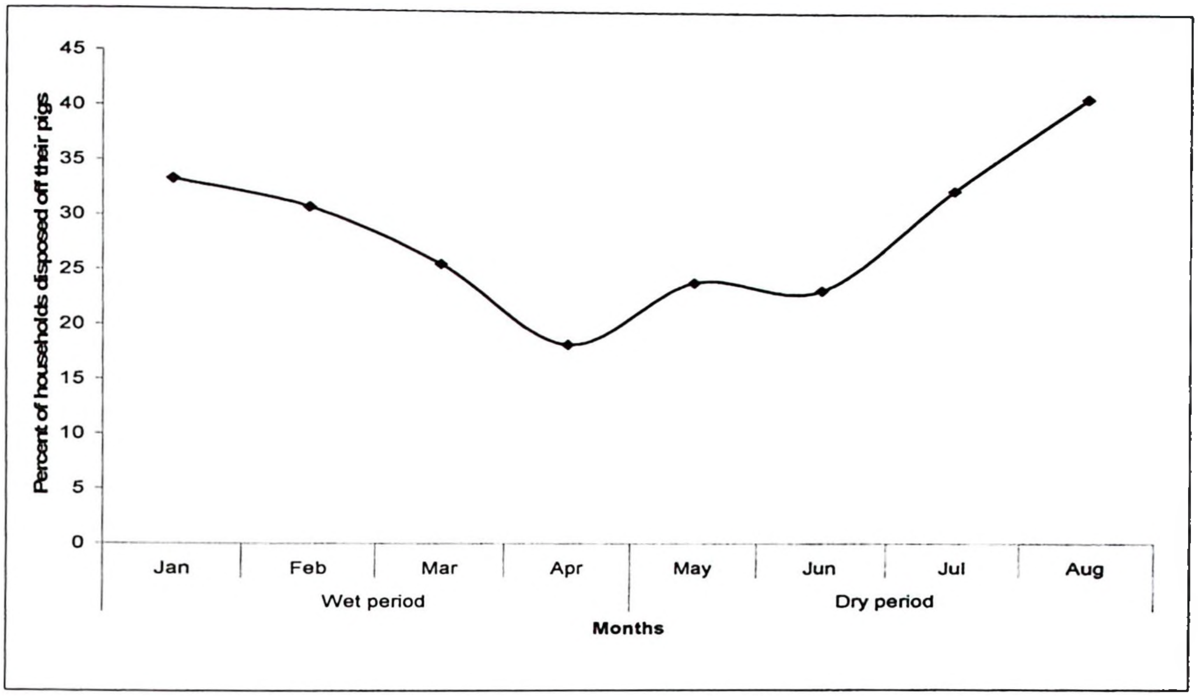

Figure 21: Seasonal variation on disposal of pigs by households from January to August 2008.

4.3.2.5 Pig off take characteristics

Table 58 shows the effects of districts and households PC prevalence status on mean off take variables in the 40 pig keepers' households monitored for 8 months. Pigs off take coefficients were estimated using different formulae as shown in equestions *(i), (ii), (iii), (iv)*, and *(v)* in section 3.2.1.3.3. The overall mean pigs' gross off take for eight monitored months (which included sales, slaughter, and lease-out) across study districts and PC prevalence status was 4.7 pigs per household. The higher proportion (90 %) of gross off take was made by pig sales, with an overall mean of 4.4 pigs per households which was equivalent to mean pig herd size per household. Mean pigs' gross off take and number of pigs sold per household were statistically similar between districts and households PC prevalence status ($P > 0.05$). Mean annual gross off take rate (AGOR) and annual sales rate (ASR) (commercial off take rate) per household across study districts and households PC prevalence status were 170.3 and 152.2%, respectively.

Table 57: The effects of districts and households PC status on mean pigs' off take variables per household

Pigs' off take variables	Districts (mean)		SEM	Overall	P value
	Mbeya rural	Mbozi		mean	
Herd size (t)[1]	4.8	3.8	0.7	4.4	0.33
Gross off take (t)	4.7	4.6	0.9	4.7	0.91
Number of pigs sold (t)	4.6	3.9	0.9	4.4	0.53
Annual gross off take rate (%)	145.6	189.7	28.1	170.3	0.28
Annual sales rate (commercial off take rate) (%)	137.7	162.7	27.4	152.2	0.52
Net off take (t)	2.4	2.5	1.0	2.4	0.89
Annual net off take rate (%)	65.4	94.3	36.8	79.0	0.58
	Household PC status (mean)				
	Negative	Positive			
Herd size (t)	4.6	4.0	0.8	4.4	0.67
Gross off take (t)	5.8	3.4	1.1	4.7	0.19
Number of pigs sold (t)	5.7	2.7	0.9	4.4	0.08
Annual gross off take rate (%)	174.7	160.6	31.8	170.3	0.78
Annual sales rate (commercial off take rate) (%)	170.7	129.0	31.7	152.2	0.42
Net off take (t)	2.0	2.9	1.0	2.4	0.62
Annual net off take rate (%)	79.7	79.9	42.6	79.0	0.99

[1] monitored period = 8 months in 40 households

Between study districts, mean AGOR and ASR per household were relatively higher in Mbozi districts. However, the differences were not statistically (P > 0.05) significant. Similarly, mean AGOR and ASR were relatively higher in households with pigs free from PC (PC negative) than infected (PC positive). However, the difference was not statistically significant (P > 0.05). Mean pigs' net off take per household across study districts and household PC status was 2.4 ± 1.0 pigs, with no significant differences between districts or household PC status (P > 0.05). Mean annual net off take rate was 79% per household across districts and household PC prevalence status, with no significant differences between districts and households PC status (P > 0.05).

On the other hand, interaction between study districts and PC status of households have shown some effects in some pig off take variables such as gross off take and number of pig sold per household (Table 59). Mean pigs' gross off take per household was significantly higher in households with PC uninfected pigs in Mbeya rural than those with infected pigs in Mbeya rural and Mbozi district (P < 0.05). There was no statistical difference on the mean pigs' gross off take between households with PC infected pigs and those uninfected in Mbozi district (P > 0.05). However, mean pigs gross off take per household was significantly (P < 0.05) higher for households with PC infected pigs in Mbozi districts than those with PC infected pigs in Mbeya rural. Similar pattern was also observed on the mean number of pig sold per household between study districts and household PC infection status. Annual gross off take rate, annual sales rate, net off take, and annual net off take rate were statistically similar for the districts and households with different PC prevalence status (P > 0.05).

Table 58: The effects of districts and PC prevalence interaction on mean pigs' off take variables per household.

Pigs' off take variable per household	District and PC prevalence interaction	LSM ± SE
Gross off take	MR[1] * PC - negative	8.1 ± 1.6^{a}
	MR* PC -positive	1.3 ± 1.9^{c}
	MB[2] * PC - negative	3.6 ± 1.5^{b}
	MB* PC-positive	5.5 ± 1.3^{ab}
P value and significance		P = 0.021*
Number of pigs sold	MR * PC - negative	8.1 ± 1.6^{a}
	MR* PC -positive	1.1 ± 1.8^{c}
	MB * PC - negative	3.4 ± 1.4^{b}
	MB* PC-positive	4.3 ± 1.3^{ab}
P value and significance		P = 0.030*

[1]Mbozi district, [2]Mbeya rural districts, means within the same column having different superscripts are significantly different (P< 0.05)

4.3.2.6 Age, weight and price characteristics of pigs sold by pig keepers

Mean pig age, weight, and price for pigs sold by the 40 monitored households are shown in Table 60. Mean age of pigs sold by pig keepers was 10.7± 9.2 months. Age of pigs sold ranged between 2 and 51 months, where's most (79.4 %) of them ranged between 2 and 12 months. Mean price per kg live body weight varied with age groups. Price per kg live body weight ranged from TZS 634.9 to 2771.4 with mean of TZS 1202.4 ± 453.2. On the other hand, live body weight of pigs sold by pig keepers ranged between 7 and 110 kg with mean of 32.0 ± 23.8 kg

Table 59: Mean pig age, weight, and price for pigs sold by 40 monitored households

Variable	n[1]	Mean ± s.d	Min	Max
Age (months)	150	10.7± 9.2	2	51
Live weight (kg)	150	32.0 ± 23.8	7	110
Price per kg live body weight (TZS)	150	1202.4 ± 453.2	634.9	2771.4

[1] number of pigs

Age, weight, and price distribution of pigs sold by pig keepers are shown in Table 61. Price per kg live body weight was highest for pigs with ages between two and four months (weaners) compared to other age groups. There was no consistent trend of age and prices for pig age groups above four months. Most pigs (71.4 %) were sold at weights between 7 and 40 kg. Similarly as in pig age groups and price relationship, price per kg body weight was highest for younger (weaners) pigs between 7 and 10 kg body weight compared to pigs above 10 kg body weight.

High significant positive correlation ($P < 0.001$, $r = 0.925$) between live weight of pigs sold with price paid per kg live body weight was observed (Table 62). On the other hand, correlation between ages of pigs and price per kg live body weight showed a significantly negative correlation between these two variables ($P < 0.01$, $r = - 0.251$).

Table 60: Pig age, weight, and price (TZS) distribution of 150 pigs sold by pig keepers in 40 monitored households

Age and weight groups	Number of pigs (%)	Price per kg live body weight (Mean ± s.d.)
Age group (months)		
2- 4	31 (20.7)	1764.7± 680.6
4.1 – 6	15 (10.0)	1007.6 ± 210.5
6.1 – 8	34 (22.7)	1073.9 ±189.5
8.1 – 12	39 (26.0)	1051.8 ±162.2
12.1 – 16	5 (3.3)	957.5 ± 249.3
16.1 - 20	13 (8.7)	1232.2 ± 166.9
20.1 – Max	13 (8.7)	939.1 ± 155.3
Weight group (kg		
Min- 10	28 (18.7)	1809.6 ± 703.8
10.1 – 20	40 (26.7)	1086.0 ± 198.4
20.1 – 30	19 (12.7)	1018.3 ± 116.5
30.1 – 40	20 (13.3)	1102.6 ± 250.2
40.1 – 50	18 (12.0)	1049.8 ±165.8
50.1 – 60	7 (4.7	963.3 ± 89.6
60.1 - max	18 (12.0)	1067.8 ± 229.4

Table 61: Partial correlation between price per kg live body weight and pig age and weight for pigs sold by pig keepers

Variable	Correlation	Significance and P value
Pig weight (kg)	0.925	< 0.001***
Pig age (month)	- 0.251	0.002**

• P < 0.05, ** P< 0.01, *** P< 0.001,

4.3.2.7 Access to and sources of market information to pig keepers

Access to and sources of market information to pig keepers are presented in Table 63. Very few pig keepers had access to market information on market prices for pig and types of pigs required. Furthermore, for those who had access to market information, the main source of information was from other pig keepers and a few from pig traders.

Table 62: Acquisition and sources of market information to pig keepers

Access to market information (N=291)	Number of households (%)
Yes	54 (18.6)
No	237 (81.4)
Sources of information (N = 59)	
Other pig keepers	46 (85.2)
Pig traders	13 (24.1)

4.3.3 Pig marketing chain characteristics at intermediate and terminal (traders) level

4.3.3.1 Demographic and socio-economic characteristics of pig traders

Table 64 shows gender, education level, and age of different types of pig traders. Pig trading was highly (94 %) dominated by male pig traders. Majority (85.5 %) of pig traders had primary education, while relatively few of them had secondary education. Mean age of pig traders was 33.5 ± 8.0 years, with relatively little variation between different types of pig traders. Butchers and pig collecting agents had higher mean ages, than pork processors and retailers.

Table 63: Demographic characteristics of different types of pig traders

Type of pig traders	n[1]	Gender n (%)		Education level n (%)			Age
		Male	Female	informal	Primary	Secondary	(mean ± s.d)
Butcher	19	18 (95)	1 (5)	0 (0.0)	17 (89.5)	2 (10.5)	38.6 ± 8.9
Pork processors (PP)	18	14 (78)	4. (22)	2 (11.1)	16 (88.9)	0 (0.0)	30.2 ± 8.0
Pork centre operators (PCO)	70	67 (96)	3 (4)	6 (8.6)	60 (85.7)	4 (5.7)	32.7 ± 7.5
Retailers	4	4 (100)	0 (0)	0 (0.0)	4 (100.0)	0 (0.0)	30.5 ± 4.7
Pig transporters (PT)	9	9 (100)	0 (0)	0 (0.0)	5 (55.6)	4 (44.4)	35.1 ± 6.5
Pig collecting agents (PCA)	4	4 (100)	0 (0)	0 (0.00	4 (100.0)	0 (0.0)	38.0 ± 8.5
Total	124	116 (94)	8 (6)	8 (6.5)	106 (85.5)	10 (8.1)	33.5 ± 8.0

[1]Number of pig traders

Experience in pig business by pig trader, districts and location of pig business are given in Table 65. Experiences in pig business varied greatly depending on type of pig trader, study districts, and location of the pig business. Among the six types of pig traders, butchers had longest experience in pig business, followed by pig collecting agents. Notably, pig keepers' ages and experiences were positively correlated ($r = 0.45$, $P < 0.05$). Pig retailers had the lowest (4 years) experience. Among the study districts, pig traders in Mbeya urban district had higher experience in pig business than counterparts in Mbeya rural and Mbozi districts. Pig traders located in urban areas had more experience in pig business, followed by those in peri urban and lastly for those in rural areas.

Table 64: Experience in pig business by pig trader, districts, and location of pig business

Type of pig trader, district and location of pig business	Number of traders	Pig trading experience (years) Mean ± s.d
Type of pig trader		
Butcher	19	7.9 ±5.8
PP	18	6.8 ±7.6
PCO	70	5.8 ±4.8
Retailer	4	4.0 ±3.4
PT	9	5.3 ±3.7
PCA	4	7.0 ±4.3
Study districts		
Mbeya urban	31	7.8 ± 6.7
Mbeya rural	39	6.6 ± 5.5
Mbozi	54	5.0 ± 4.1
Location of pig business		
Rural	63	5.4 ±4.7
Urban	39	7.2 ± 5.1
Peri urban	22	6.7 ±7.0

4.3.3.2 Pig traders' profiles: time allocation, types and sources of products

Time allocated to pig trading by pig traders

Table 66 shows time allocation to pig business based on type and location of pig business. Time allocated for pig business varied among and between types of pig traders and locations of pig business. Among the six types of pig traders, 78.9 % of butchers were fully time engaged in pig business, followed by 72.2 % PP and 66.7 % PT. In this context, these traders were engaging most of their time in the pig business and thus making it a main employment. Among pig traders, PCO were mostly (61.4 %) on part time or infrequently engaged. Full time pig business engagement was more dominant in urban areas followed by peri urban, while, part- time was dominant in rural areas.

Table 65: Extent of engagement in pig business by different pig traders

Type of pig trader and business location	N	Time committed to pig business	
		Full time duty n (%)	Infrequent & part time duty n (%)
Type of pig trader			
Butcher	19	15 (78.9)	4 (21.1)
PP	18	13 (72.2)	5 (27.8)
PCO	70	27 (38.6)	43 (61.4)
Retailer	4	2 (50.0)	2 (50.0)
PT	9	6 (66.7)	3 (33.3)
PCA	4	2 (50.0)	2 (50.0)
Total	124	65 (52.4)	59 (47.6)
Location of pig business			
Rural	63	19 (30.2)	44 (69.8)
Urban	39	31 (79.5)	8 (20.5)
Peri urban	22	15 (68.2)	7 (31.8)
Total	124	65 (52.4)	59 (47.6)

Types of pig products and locations where pig traders purchased products

Categories of pig products bought by different pig traders in different locations of pig businesses are presented in Table 67. Live pigs and pork (fresh and cooked) were the main products traded by pig traders. Pig traders were also comparatively specialised to certain pig products in their pig/pork business. Pig traders such as retailers, PT and PCA purchased only live pigs, while, 80 % of PCO and 73.7 % of butchers purchased live pigs as main input to their business.

Table 66: Categories of pig products bought by different pig traders and by locations of pig businesses

Type and location of pig business	Number of traders	Category of product bought by trader		
		Live pig only n (%)	Fresh pork only n (%)	Both live pig and fresh pork n (%)
Type of pig business				
PCO	70	56 (80.0)	1 (1.4)	13 (18.5)
Butcher	19	14 (73.7)	2 (10.5)	3 (15.8)
PT	9	9 (100.0)	0 (0.0)	0 (0.0)
Retailer	4	4 (100.0)	0 (0.0)	0 (0.0)
PCA	4	4 (100.0)	0 (0.0)	0 (0.0)
PP	18	2 (11.1)	15 (83.3)	1 (5.6)
Total	124	89 (71.8)	18 (14.5)	17 (13.7)
Pig business location				
Rural	63	53 (84.1)	5 (7.9)	5 (7.9)
Urban	39	21 (53.8)	7 (17.9)	11 (28.2)
Peri urban	22	15 (68.2)	6 (27.3)	1 (4.5)
Total	124	89 (71.8)	18 (14.5)	17 (13.7)

Fresh pork was purchased mainly by PP, moreover, relatively few PCO and butchers as well purchased live pigs and fresh pork. Live pigs were the most dominant pig product purchased by 71.8 % of pig traders, the extent varied across different business locations. Pig traders purchasing live pigs were dominant (84 %) in rural areas, followed by peri urban (68.2 %) and lastly in urban areas (53.8 %).

Places where different pig traders purchased pigs and pork are presented in Table 68. Locations (i.e. within village/street, inter-village/street (neighbouring), far villages within district, across districts, and across regions) where pigs' products (live pigs and fresh pork) were purchased by pig traders varied. However, 89.5 % of the traders purchased products within their villages or streets and 81.5 % extended to neighbouring villages or streets.

Table 67: Places where pig/pork were purchased by different pig traders

Pig traders	N = 124	Location where pigs/ pork were purchased by trader				
		L^1	L^2	L^3	L^4	L^5
		n (%)	n (%)	n (%)	n (%)	n (%)
Butcher	19	18 (94.7)	17 (89.5)	10 (52.6)	11(57.9)	0 (0.0)
PP	18	9 (50.0)	10 (55.6)	4 (22.2)	2 (11.1)	0 (0.0)
PCO	70	69 (98.6)	60 (85.7)	38 (54.3)	15 (21.4)	2 (2.9)
Retailers	4	4 (100.0)	4 (100.0)	4 (100.0)	3 (75.0)	0 (0.0)
PT	9	7 (77.8)	7 (77.8)	3 (33.3)	6 (66.7)	2 (22.2)
PCA	4	4 (100.0)	3 (75.0)	3 (75.0)	3 (75.0)	1 (25.0)
Total	124	111 (89.5)	101 (81.5)	62 (50.0)	40 (32.3)	5 (4.0)

[1] Close locations (within village or streets), [2] inter villages (i.e. neighbour villages, streets), [3] relatively distant locations within district, [4] across districts, [5] across region, total observation > 100 % due to multiple responses

About 50 % of traders purchased products from distant locations within their districts. Only a few (32.3 %) of pig traders purchased products across districts and across regions (4 %). In this context, extent of coverage during the process of buying live pigs and fresh pork varied between different types of pig trading (Table 69).

Table 68: Variation by different traders on extent of coverage during buying live pigs and pork

Pig traders	Extent of coverage		Odd ratio	95% CI	P value and significance
	A[1] (%)	AB [2] (%)			
PP	13 (72.2)	5 (27.8)	Ref (1.0)		
Butcher	5 (26.3)	14 (73.7)	7.3	1.71 – 31.08	0.007**
PCO	29 (41.4)	41 (58.6)	3.7	1.18 – 11.44	0.025*
Retailers	0	4 (100.0)	-	-	-
PT & PCA	4 (30.8)	9 (69.2)	5.9	1.22 – 28.00	0.027*
Total	51 (41.1)	73 (58.9)	-	-	-

PP was used as the reference category, [1] buy pigs within and neighbouring villages/streets only, [2] buy pigs within, neighbouring and far villages, * P < 0.05, ** P< 0.01, *** P< 0.001,

4.3.3.3 Number and prices of pigs purchased by pig traders

Number of pigs purchased by different pig traders under different pig business environment

Mean monthly number of pigs purchased by pig traders based on districts, type of pig traders, business location, pig traders' time commitment in pig business, and educational level are presented in Figure 23. Mean number of pigs purchased per month by pig traders varied depending on different factors including district, type of pig trading, location of pig business, condition of pig business and education level of pig trader. Mean monthly number of pigs purchased per trader in Mbeya urban district was higher compared to those purchased by traders in Mbeya rural and Mbozi districts. Among pig traders, PT had higher mean number of pigs purchased per month. On the other hand, pig traders in peri-urban areas had higher mean monthly number of pigs purchased than their counterparts in urban and rural areas. Pig traders on full-time pig trading had higher mean number of pigs purchased per month compared to pig traders practising part time and/or infrequent pig business. Pig keepers with secondary education had a higher mean of pigs purchased than pig traders with primary or non-formal education

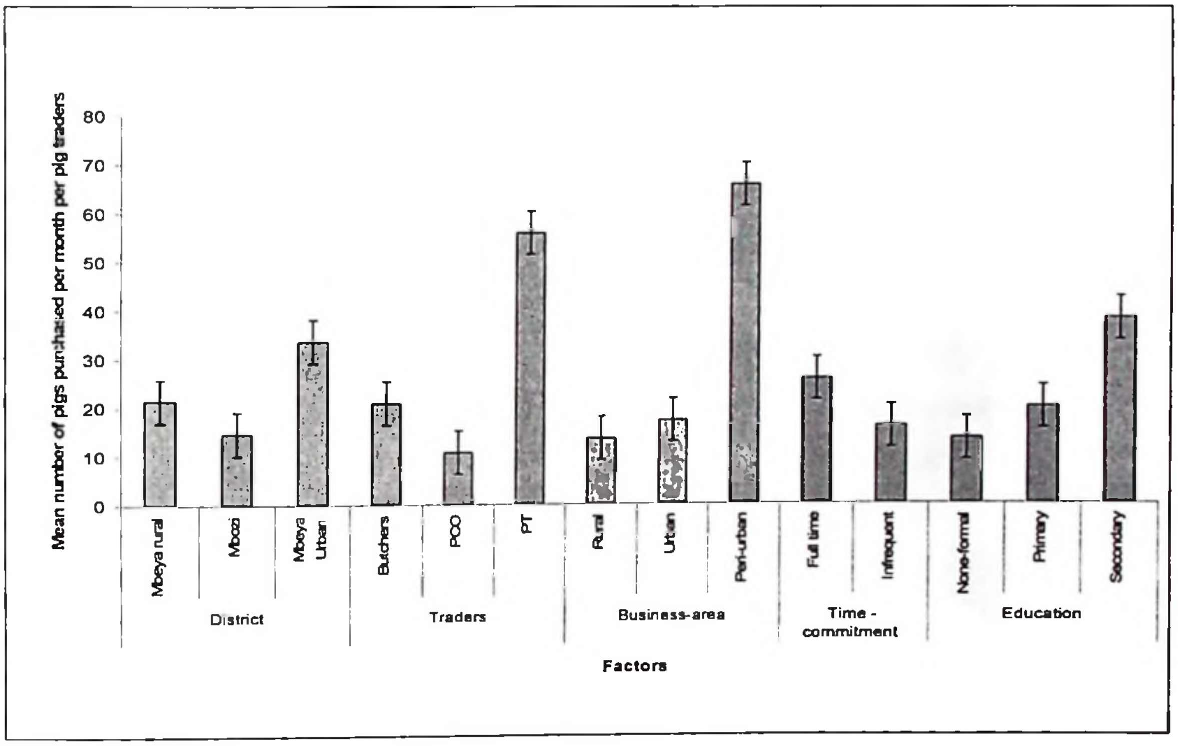

Figure 22: Mean monthly number of pigs purchased by pig traders under different environment

Influence of different factors on pigs purchasing price by traders

Purchasing price per kg live weight of pigs by district, types, and locations of pig business are shown in Table 70. The mean purchasing price per kg live weight of pig was higher (TZS 1454.2 ± 473.6) in Mbeya urban, followed by Mbeya rural (TZS

1206.5 ± 184.5) and lowest (TZS 1057.2 ± 313.4) in Mbozi district. Pig purchasing price also varied depending on the type of pig trader. Butchers had higher mean purchasing price per kg live weight, followed by PT and retailers, while, PCO had the lowest price per kg live weight of pig. Similarly, higher mean purchasing price for pigs were observed for pig traders located in urban area compared to their counterparts located in peri urban and rural areas.

Table 69: Traders' purchasing price (TZS) per kg live-weight (lwt) of pigs by district, type, and location of pig business

District, business type and location	n[1]	Price per kg lwt (Mean ± s.d)
Districts		
Mbeya urban	17	1454.2 ± 473.6
Mbeya rural	29	1206.5 ± 184.5
Mbozi	28	1057.2 ± 313.4
Overall mean	74	1206.8 ± 348.4
Type of pig business		
Butcher	18	1446.7 ± 468.1
PCO	46	1077.2 ± 269.7
PT & retailers	13	1303.9 ± 128.9
Overall mean	74	1206.9 ± 348.4
Location of pig business		
Urban	26	1416.5± 395.1
Peri urban	7	1327.1 ± 132.1
Rural	44	1053.5 ± 257.2
Overall mean	74	1206.9 ± 348.4

[1] Number of pig traders

4.3.3.4 Access to and sources of market information by pig traders

The extent of access to and sources of market information for pig traders are given in Table 71. Most (91 %) pig traders were informed about prevailing market prices, amount, and type of products required. Major (76.6 %) source of market information to pig traders was other pig traders, through visiting each other. Other sources of market information to pig traders were pig keepers (18.5 %), particularly when they want to inform pig traders their intention to sell their pigs. Relatively few sources of information were obtained from pork consumers and traders' organisation. Physical visits to other pig traders were the most important means of information acquisition, followed by visits to pig keepers. Other means include the use of mobile phones, consumers contact during trading and traders meetings

Table 70: Access to market information for pig traders

Market information acquisition status	Extent, sources and means of information	Frequency	Percent
How well informed about the prevailing price, amount and type required (N = 124)	Well informed	113	91.1
Source of information (N = 124)	Other pig traders	95	76.6
	Pig keepers	23	18.5
	Consumers	5	4.0
	Traders' organisation	4	3.2
Means of information acquisition (N = 124)	Visits to fellow traders	98	79.0
	Visits to pig keepers	49	39.5
	Telephone	20	16.1
	Traders meetings	4	3.2
	Consumers during trading	5	4.0

4.3.3.5 Determinants of selecting pigs and pork to purchase by pig traders

Determinants of selecting pigs and pork to purchase by pig traders during the process of buying pig or pork are shown in Table 72. Pig traders used different methods and attributes to select a pig or pork to purchase based on their customers circumstances. Inspection of PC (lingual palpation of cyst) in live pigs was the most important examination ranked first by most (87 %) of pig traders. Another important examination was pig's body size, which ranked second and practised by 82.3% of pig traders. Other important examination criteria were general health status of pigs and body length of pigs, which ranked third and fourth, respectively. For pig traders (particularly PP) who normally purchased pork from other traders, the most used criterion was presence of an inspection stamp as proof that the pork has been inspected and ascertained safe by meat inspector. Type of feed fed to pigs was also used as one of criterion for buying and pricing during the process of buying pigs. According to pig traders' experiences, pigs fed concentrate were normally heavier than pig fed forages. Thus, pig traders said they preferred and paid more for pigs fed concentrate rations than forages. The least criteria indicated by pig traders include background history of pig and pig coat colour, which ranked seventh and eighth respectively.

Table 71: Determinants of selecting pigs and pork to purchase by pig traders during the process of buying pig or pork

Determinant	Proportion of traders using a determinant (N = 124)		Score [1]	Rank
	Frequency	Percent		
Presence of PC	108	87.1	287	1
Body size score	102	82.3	195	2
General health status	48	38.7	67	3
Body length	28	22.6	46	4
Presence of inspection stamp	14	11.3	14	5
Type of feed fed to pig	7	5.6	9	6
Background history of pig	3	2.4	5	7
Coat colour	2	1.6	1	8

[1] Score calculated as cumulative cross product of frequency and rank weight given to each criterion by each respondent in the cross-sectional study

4.3.4 Pig traders' PC experiences, and risk behaviours influenced PC transmission

4.3.4.1 Accessibility, types of pig slaughter facilities and extent of meat inspection

Accessibility and type of pig slaughter facilities used by pig traders

Types of pig slaughter facilities accessed by different pig traders are shown in Table 73. Private/personal slaughter slabs were the most used facility by pig traders, followed by official abattoirs and slabs and lastly village slaughter slabs. About 17.4 % of pig traders slaughtered pigs at their homes with no specific slaughter facility, while, about 5.8 % had no specific slaughter facility. Extent of use of different slaughter facilities varied with different pig traders. Official abattoirs and slabs facilities were more commonly used by butchers, while, private and personal slaughter slab were more commonly used by PCO.

Types of pig slaughter facilities accessed by pig traders in different locations of pig business are presented in Table 74. In rural areas private/personal slaughter slabs were the most dominant slaughter facility used by majority of pig traders, followed by village slaughter slabs. On the other hand, in rural areas home slaughters were quite common compared to urban and peri urban areas. In urban areas, official abattoirs and slaughter slabs were the most used slaughter facilities, followed by private/personal slaughter slabs. In peri-urban area, pig traders accessed mainly private/personal slaughter slabs.

Table 72: Types of pig slaughter facilities accessed by pig traders

Slaughter facility	Butcher	PCO	Total
	N1 = 19	N2 = 66	N = 86
	n (%)	n (%)	n (%)
Official abattoirs and slabs [1]	13 (68.4)	6 (9.1)	19 (22.1)
Private and personal slaughter slab [2]	5 (26.3)	33 (50.0)	38 (44.2)
Slaughters at home [3]	1 (5.3)	15 (22.7)	15 (17.4)
Village slaughter slab [4]	0 (0.0)	9 (13.6)	9 (10.5)
None	0 (0.0)	5 (7.6)	5 (5.8)

[1] Owned and managed by government (local government), [2] Owned and managed by individual or group of traders, [3] No specific slaughter facility, [4] owned and managed by village government

Table 73: Types of pig slaughter facilities accessed by locations

Type of slaughter facility	Rural	Urban	Peri urban	Total
	N1 = 51	N2 = 30	N3 = 5	N = 86
	n (%)	n (%)	n (%)	n (%)
Official abattoir and slabs	4 (7.8)	15 (50.0)	0 (0.0)	19 (22.1)
Private/personal slaughter slab	21 (41.2)	12 (23.5)	5 (100.0)	38 (44.2)
Slaughters at home	13 (25.5)	2 (3.9)	0 (0.0)	15 (17.4)
Village slaughter slab	8 (15.7)	1 (2.0)	0 (0.0)	9 (10.5)
None	5 (9.8)	0 (0.0)	0 (0.0)	5 (5.8)

Pork inspection services: Access to and frequency of inspection

Table 75 shows access to inspection services and frequency of pork inspection by pig traders. Village and ward extension officers were the main responsible persons for pork inspection across study locations. Only about 18 % of pig traders had access to specialised meat inspectors, while, 10.7 and 6.0 % of pig traders obtained inspection services from nominated person by village government and health officer and/or dispensary nurse, respectively. In rural areas, village followed by ward extension officers were the main (72 %) persons responsible for pig/pork inspection services. In urban areas pig/pork specialised meat inspectors predominantly did inspection services. Moreover, village and ward extension officers were also involved to some extent in pork inspection services. In peri urban areas, village extension officers did pig/pork inspections.

Table 74: Access to inspection services and frequency of pork inspection

Person responsible for pig/pork inspection	Access to inspection services by location of pig business			Total
	Rural	Urban	Peri urban	
Number of pig traders	N1 = 49	N2 = 30	N3 = 5	N = 84
	n (%)	n (%)	n (%)	n (%)
Village extension officer	20 (40.8)	10 (33.3)	5 (100.0)	35 (41.7)
Ward extension officer	15 (30.6)	5 (16.7)	0 (0.0)	20 (23.8)
Nominated person by village government	9 (18.4)	0 (0.0)	0 (0.0)	9 (10.7)
Health officer & dispensary nurse	5 (10.2)	0 (0.0)	0 (0.0)	5 (6.0)
Specialised inspector	0 (0.0)	15 (50.0)	0 (0.0)	15 (17.8)
Total	49 (100.0)	30 (100.0)	5 (100.0)	84 (100.0)

Frequency of pig/pork inspection by location	Rural	Urban	Peri- urban	Total
	N1 =51	N2=30	N3=5	N=86
Always	22 (43.1)	29 (96.7)	1(20.0)	52 (60.5)
Occasionally	27 (52.9)	1 (3.3)	4 (80.0)	32 (37.2)
Never done	2 (3.9)	0 (0.0)	0 (0.0)	2 (2.3)
	51 (100.0)	30 (100.0)	5 (100.0)	86 (100.0)

Frequency of pigs/pork inspection varied between different location of pig business and slaughter facilities. About 60.5 % of pig traders said they always get inspection services for their slaughtered pigs. Nevertheless, 37.2 % of pig traders obtained pork inspection services only occasionally, while, 2.3 % had no access to any of service. Between different players in the pig business, majority of pig traders in urban areas had always access inspection services compared to their counterparts in peri urban and rural areas. On the other hand, majority of pig traders in peri urban, followed by rural areas had access to pork inspection services occasionally. About 4 % of pig traders in rural areas had no access to inspection services.

Differences in the accessibility of inspection services were also observed in different types of slaughter facilities (Table 76). Pig traders connected to official slaughter abattoirs and slabs had more access to inspection services, followed by private/personal slabs, and lastly by village slaughter slabs. Pork inspection was rarely done at village slaughter slabs, followed by home slaughter and private/personal slabs.

Table 75: Frequency of pigs/pork inspection under different slaughter facilities

Type of slaughter facility	N = 86	Frequency of pork inspection		
		Always done n (%)	Occasionally done n (%)	Never done n (%)
Official slab/abattoir	N1 =19	17 (89.5)	2 (10.5)	0 (0.0)
Private/personal slabs	N2=38	24 (63.2)	13 (34.2)	1 (2.6)
Slaughter at home	N3=15	8 (53.3)	6 (40.0)	1 (6.7)
Village slaughter slabs	N4=9	3 (33.3)	6 (66.7)	0 (0.0)
No defined facility	N5= 5	0 (0.0)	5 (100.0)	0 (0.0)
Total	86	52 (60.5)	32 (37.2)	2 (2.3)

4.3.4.2 Knowledge and sources of information about PC by pig traders

Awareness and knowledge of PC by pig traders

Table 77 shows partial correlation between period pig traders got awareness of PC with period started pig business and age of pig traders. Generally, all pig traders were aware of PC, however, periods pig keepers got aware varied (Appendix 11). About 44.3 % of traders got awareness of PC recently between 2000 and 2007. Some pig business variables influenced their awareness of PC. Year (period) when pig traders got aware was significantly positively correlated with year when started pig business ($r = 0.362$, $P < 0.001$). On the other hand, traders' PC awareness was significantly negatively correlated with traders age ($r = -0.381$, $P < 0.001$).

Table 76: Partial correlation between periods pig traders got awareness of PC with period started pig business and age of pig traders

Variable	Correlation	Significant and P-value
Year when trader started pig business	0.362	< 0.001***
Age of pig trader	-0.381	< 0.001***

*** P< 0.001,

The extent of pig traders' knowledge on how pigs are infected with PC is shown in Table 78. Moderately few (38.7 %) of pig traders had knowledge on how pigs were infected with PC. Some differences were observed among pig traders on the extent of this knowledge; however, variations were not statistically different ($P > 0.05$). Similar situation was also observed in different locations of pig business (Table 78).

Table 77: Extent of pig traders' knowledge on how pigs are infected with PC

Type and location of pig business	N	Knowledge on how pig get infected	
		Knowledgeable n (%)	Unknowledgeable n (%)
Type of traders			
Butcher	19	10 (52.6)	9 (47.4)
PP	18	6 (33)	12 (67)
PCO	70	24 (34)	46 (65.7)
Retailer	4	1 (25)	3 (75)
PT	9	5 (55.6)	4 (44.4)
PCA	4	2 (50.0)	2 (50.0)
Total	124	48 (38.7)	76 (61.3)
P value for chi square		0.556	
Location of pig business			
Rural	63	19 (30.2)	44 (59.8)
Peri urban	22	11(50.0)	11 (50.0)
Urban	39	18 (46.2)	21 (53.8)
Total	124	48 (38.7)	76 (61.3)
P value for chi square		0.133	

Awareness and knowledge of pig traders on zoonotic relationship between cysticercosis in pigs and human

Table 79 shows Traders awareness on whether PC is a meat borne zoonosis. Awareness of pig traders that PC infected pork can affect human was generally low (26 %). Furthermore, level of knowledge on zoonotic relationship between PC infected pork and human was very low; with only 11.3 % of traders had knowledge on how human is affected by PC infected pork. Levels of awareness and knowledge that PC is a meat borne zoonosis was statistically similar between different types of pig traders and different location of pig business (P > 0.05).

Table 78: Traders awareness on whether PC is a meat borne zoonosis

Type and location of pig business	N	Proportion of traders aware that the PC infected pork can affect human n (%)	Proportion of traders knowledgeable on how PC infected pork infect human n (%)
Type of traders			
Butcher	19	7 (36.8)	2 (10.5)
PP	18	1 (5.6)	0
PCO	70	21 (30.0)	9 (12.9)
Retailer	4	0	0
PT	9	2 (22.2)	2 (22.2)
PCA	4	1 (25.0)	1 (25.0)
Total	124	32 (25.8)	14 (11.3)
P value for chi square		0.21	0.44
Location of pig business			
Rural	63	15 (23.8)	7 (11.1)
Urban	39	13 (33.3)	5 (12.8)
Peri urban	22	4 (18.8)	2 (9.1)
Total	124	32 (25.8)	14 (11.3)
P value for chi square		0.38	0.91

[1] Number of traders

Sources of information for pig traders about PC are presented in Table 80. Pig traders were the main source of information about PC for their fellow pig traders, followed by extension officers. Pig keepers and other sources such as relatives, short courses and own initiatives also provide information to traders.

Table 79: Sources of information to pig traders about PC

Source of information about PC	Number of pig traders (N = 124) n (%)
Other pig traders	71 (57.3)
Extension officers	39 (31.4)
Pig keepers	10 (8.1)
Others	4 (3.2)
Total	124

4.3.4.3 PC challenges among pig traders and existing copping strategies

Techniques used by pig traders to identify whether pig or pork was PC infected

Different techniques used by pig traders to identify pig and pork infected with PC are given in Table 81. Tongue examination for cysts was the method used by most pig traders. Examination of cyst by incision of pig masseter muscles of live pigs was among used methods by pig traders. According to traders' explanation, this technique was mainly used when there was uncertainty on the PC status of intended pig if the lingual palpation technique failed to detect the infection. The incised pigs were normally slaughtered within a day or hours after the exercise. Other techniques included eye-lid examination for cyst and pulling pig's back-hairs along the backbone lining. Traders claimed that, the type of screaming when pulling back-hair would alert the possibility of cyst infection. For pig traders purchasing fresh pork from other traders such as butchers the most used techniques were to gaze if the meat was stamped to evidence that the pork was inspected, and buying pork from trusted butcher.

Table 80: Different techniques used by pig traders to identify pig and pork infected with PC

Technique used	Number of respondents (N = 122) n (%)
Tongue examination	106 (86.8)
Examination/incise the masseter muscle	15 (12.3)
Eye lid examination	9 (7.4)
Pull back-hairs of pig	6 (4.9)
Look for inspection stamp	11 (9.0)
Inspecting the meat	3 (2.5)
Buy from trusted butcher	2 (1.6)

4.3.4.4 Experience of pig traders on PC infected pigs in their business and existing coping strategies

Table 82 shows experiences of different pig traders with cases of PC infected pigs in their business in relation to type of business and extent of traders' coverage. Experiences of PC infected pigs varied between pig traders and extent of pig business coverage. Among pig traders, PP experienced comparatively few cases of PC in their pig business. Butchers had higher risk of PC cases than PP (OR = 5.1, $P<0.05$). PCO experienced the highest odd ratio (22.9) of PC in their business relative to the reference group ($P < 0.05$). Furthermore, traders with more places of coverage during the process of buying pigs had experienced significantly higher cases of PC in their business than their counterparts with limited coverage (those buying pigs within theirs and neighbouring villages only) (OR = 4.7, $P < 0.01$,)

Table 81: Experience of pig traders on cases of PC infected pig(s) in their business

Type of pig business	N	Traders experienced PC cases n (%)	Logistic regression		
			Odd ratio	95 % CI	P value
PP	18	4 (22.2)	1.0 (ref)	-	-
Butchers	18	13 (72.2)	5.1	1.01 – 26.02	0.048*
PCO	67	59 (88.1)	22.9	5.62 – 93. 40	< 0.001***
PT & PCA	13	10 (77.0)	8.0	1.32 – 48.20	0.024*
Extent of trader coverage					
A [1]	49	28 (57.1)	Ref (1.0)	-	-
AB [2]	71	62 (87.3)	4.7	1.60 – 13.93	0.005**

* P < 0.05, ** P< 0.01, *** P< 0.001, [1] traders with limited coverage in the process of buying pigs (i.e. within and neighbouring villages only), [2] traders with extended coverage in the process of buying pigs

Pig traders were using different techniques to sell PC infected pork (Table 83). Selling infected pork at reduced price was among the dominant technique used by high proportion of pig traders. Other important techniques involved mixing PC infected pork with non-infected ones, and PC infected pork sold at clandestine environment (i.e. selling at home, villages/places with no extension officers or dark hours) which also account for 19 % of pig traders. PC infected pork was battered for other items such as crop/grain items as expressed by 16 % of pig traders, whereas 16 % of pig traders said extended boiling of PC infected pork, followed by frying was among techniques used. Some traders removed the infected parts and sold the clean portion of carcase. While, about 3% of pig traders said there were no limitation/restriction of selling PC infected pork in their business areas.

Table 82: Different techniques used by pig traders to sell PC infected pork

Technique used to sell infected pork	Respondents (N = 70) n (%)
Sold at reduced price	23 (33)
Mixed infected with non infected pork during selling	13 (19)
Sold at clandestine background*	13 (19)
Bartered with other items	11 (16)
Extended boiling followed by frying	11 (16)
Removed infected parts and sell clean portion of carcase	9 (13)
No limitation/restriction for selling PC pigs/pork	2 (3)

* Sell at home, villages/places with no extension officers, dark hours

CHAPTER FIVE

5.0 DISCUSSION

5.1 Smallholder Pig Production Systems

5.1.1 Demographic and socio-economic characteristics of smallholder pig keepers

The observed demographic and socio-economic characteristics of smallholder pig keepers in this study revealed not only characteristics of smallholder pig keepers but also their variability and similarity with other smallholder communities. For example, it was observed that most pig keepers' households were male-headed, with a considerable proportion of females headed households. The proportion of female-headed households observed in this study were closely similar to those reported by Gimbi (2006) addressing smallholder dairy keepers in Rungwe district, Mbeya region in Tanzania. However, it was higher than those reported by Lyimo (2006) of 8 % from smallholder dairy keepers at Turiani in Mororogo region in Tanzania and lower than that reported for national rural female household heads of 23 % (NBS, 2007). The observed variations of household head might have been caused by differences in the nature of smallholder agricultural enterprises, location of the study and cultural settings (i.e. polygamous or monogamous). Marital status of household was another important socio-economic factor influencing agriculture production. In this study, most of the pig keepers' households were married, showing a typical feature of smallholder farmers under village conditions, whereby marriage life start early and sustained more in lifetime (NBS, 2002, 2007). Married households were expected to have children who determine the size of household family members anticipated to provide supplementary household labour for pig production.

The household head illiteracy level in this study was lower compared to general illiteracy rate (31%) of smallholder households in Tanzania (URT, 2005) and overall national illiteracy rate (28.6 %) (URT, 2009). This observation was also consistent with a review study by Mugo *et al.* (2001) whereby about 85 % of household had attained primary education, while, 15 % had no formal education in Embu, Kenya. On the other hand, Urassa and Raphael (2001) reported majority of smallholder farmers in Morogoro Municipal to have at least secondary school education suggesting that smallholder farmers located in urban areas attained higher level of education than those located in rural areas. Nevertheless, the observed level of education for smallholder pig keepers revealed their potential to adopt agricultural knowledge and innovations. Education has been demonstrated as an important socio-economic factor enhancing capabilities of farmers to adopt new agricultural innovations and consequently improving productivity (Rola-Rubzen and Gabunada, 2003; Alene and Manyong, 2006). The observed literacy level of pig keepers offers potential likelihood for improving productivity of smallholder pig keepers if provided with suitable innovations.

Household size is among the imperative factors in smallholder production environment because it is linked with household labour, which is key factor in smallholder production (Lüdeke, 2001; NBS, 2002). Moreover, age of household head and age-group size distribution in the household are specifically more crucial as they are associated with effective household labour and independency or dependency tendency in the households (NBS, 1993). The observed mean age of households' heads is within active age group for effective agricultural enterprises as suggested by Nyagori (2001) and Tchale (2009). Mean households heads' age was however, comparatively lower compared to those reported from studies in smallholder dairy keepers (Mulangila, 1997; Staal *et al.*, 1998; Mollel *et al.*, 1999; Luoga, 2005 and Gimbi, 2006). This observation implied that relatively young smallholder farmers were able to engage in pig keeping industry at an earlier age compared to dairy farming, probably due to comparatively less capital and technology needed. Among pig keepers' household age groups, ages between 15 and 55 years comprised a comparatively larger proportion per household. The proportion of this age group implied the potential active labour force for pig production activities. On the other hand, the observed smallholder pig keepers mean household size was relatively higher than mean national agricultural household size of 5.0 (URT, 2006). Since most of smallholder agricultural production systems in most developing countries and Tanzania in particular depend mainly on household labour, therefore, bigger household size provide opportunity for labour supply (URT, 2000; 2005; Jera and Ajayi, 2008). However, studies have shown the level of dependency among members of household increases with increasing household size; consequently, if a level of dependency rises then extent of household poverty also increases (NBS, 1993, 2002). According to the NBS (1993), household size of seven individuals or more are two thirds more likely to be poor than those living in households of six or less.

Land is one of vital resource in agricultural production and an important factor in livestock production systems (ILRI, 1995; Wilson, 1995; Rao and Birthal, 2002). Mean land size owned by smallholder pig keepers (2.0 ha) was similar to land size owned by general smallholder farmers in Tanzania which ranged between 0.9 and 3.0 ha (PADEP, 2003; Sarris *et al.*, 2006). Mean land size was also in agreement with land size owned by smallholder dairy keepers in Rungwe district, Mbeya region in Tanzania

(Lerenius and Skarback, 1987; Gimbi, 2006). Land size was however, lower than land size owned by smallholders' elsewhere; such as dairy keepers in Gambia with mean land size of 5.5 ha (Somda *et al.*, 2003) and dairy keepers in Chikomba, Kadoma and Matobo districts in Zimbabwe with mean land size of 2.8 ha (Chawatama *et al.*, 2005). Land size similarity and variation between different production systems and countries might have been attributed to variations or similarities on land tenure systems, agro-ecology, and farming systems, and type of agricultural enterprises. The observed land size variation between study districts implied differences in agro-ecology and farming systems, which might consequently, influences disparity in population density and thus different land use for crops and livestock production. In Mbeya rural district 80 % of pig keepers owned land between 0.1 and 2 ha, while, similar amount of land in Mbozi district was owned by 51 % of pig keepers. Land size has been shown to influence intensity and type of production, such as type of production systems used by livestock keepers (ILRI, 1995; Sere and Steinfeld, 1996; Rao and Birthal, 2002).

Economic activities of smallholder pig keepers under crop-livestock integrated system

Crop farming, livestock keeping and petty businesses were narrated as most important economic activities in the farming system involving smallholder pig keepers. This scenario reflects the coexistence of interactions of various components (i.e. crop-crop, crop-livestock, livestock-livestock, farm-household and farm-off farm activity components) in the system involving smallholder pig keepers as means of sustaining their livelihood. Moreover, interaction may result into trade-offs or compromises, competition or complementarily while meeting the multiple objectives of the pig keepers households. Different studies have shown the importance of integrated systems especially crop-livestock system, commonly called mixed crop-livestock system in the livelihood of smallholder farmers and as a backbone of agricultural development in developing world (Wilson, 1995; Rao and Birthal, 2002; Devendra *et al.*, 2005; Sulc and Benjamin, 2007; Franzluebbers, 2007). It is estimated that about 678 million poor are livestock-keepers, of whom 57 % are on mixed rain-fed farms, while, 23 % are landless and 20 % are practising extensive grazing (LID, 1999). Globally, mixed crop-livestock systems provide over 50 % of the output of meat (CAST, 1999). In Sub Saharan Africa, Tanzania and Mbeya in particular this system may provide more, including sustenance of smallholder livelihoods. In this context, mixed farming systems provide farmers with an opportunity to diversify risk from a single commodity, to use labour more efficiently, to have several sources of cash for purchasing farm inputs, and to add value to crops or their by-products. Moreover, small-scale pig production was practised where agricultural by-products such as maize bran, wheat, rice polishing, oil cakes, bananas and potatoes, and other leftovers are available for feeding and thus characterise mixed crop-livestock system of the study area.

Similarly, main livestock kept and importance of pig keeping in the system revealed more evidence of sub–system interaction and roles/rank of different sub-system components. Local cattle, goats, pigs, and local chicken were identified as most important livestock ranked, first, second, third and fourth, respectively among other list of livestock kept in the system. This scenario reflects livestock sub-system interaction "livestock – livestock interaction" which is very important subset of mixed crop-livestock system (Devendra *et al.*, 2005). Besides the role of complementarity, livestock-livestock interactions serve as main basis of risk aversion mechanism. The rank of pig keeping activity in livestock-livestock interactions system substantiated the roles and contribution of pig sector among other livestock classes in the system. Level of interaction is further exemplified by the proportion of pig keepers keeping other livestock, mean number of such livestock per household and variation between districts with regards to specific livestock classes. Livestock-livestock interaction might also have been used as a strategy of maximising resource use such as land, labour as well as household asset/capital as suggested by Narayan *et al.* (2000) and Kitalyi *et al.* (2005). The World Bank Report, *Voices of the Poor Initiative*, suggests that the poor focus on assets rather than income and therefore link their lack of assets (physical, human, social and environmental capital) to their vulnerability and exposure to risk (Narayan *et al.*, 2000). Moreover, livestock do not have a clear position in either framework of assets, and Morton and Meadows (2000) describe livestock under natural, financial, and social capital. However, according to NEPAD, (2006) livestock is estimated to account for 53 % of the agricultural capital stock in Sub-Saharan Africa. The practice of keeping small herd sizes of different types of livestock in the study area was typical of most smallholders' holdings in the developing countries. This tendency has major implications on socio-economic status and cultural reasons such as dowry payment or bride price (Bebe *et al.*, 2003; Moll, 2004) and rationale for maximizing returns from small holdings and risk aversion mechanisms (Udo, 1997). In this study, it was noted that crop-livestock and livestock-livestock interactions were among the important factors influencing smallholder farmers' decisions in adopting different production and/or management systems.

5.1.2 Trend and reasons for pig keeping by smallholder pig keepers

Pig keeping by smallholders is showing an exponential trend implying positive drift of smallholder farmers engaging into pig keeping activities (Fig. 11). Majority of smallholder farmers have engaged in pig keeping activities in recent years (2000–2007). Similar trend has been observed on the trend of pork production in the country (Fig. 3). The trend demonstrates the increasing importance of pig keeping enterprises in smallholder farming communities. This trend might have been attributed to various factors such as easiness of smallholder farmer to keep pigs, market access, prolific trait of pigs and profitability. Similar trend of increasing pig production by smallholder farmers has been reported in neighbouring countries such as; Uganda (FAOSTAT, 2009; Waiswa *et al.*, 2009), Kenya (FAOSTAT, 2009), Zambia (Phiri *et al.*, 2003; Sukasunge *et al.*, 2007, 2008). This trend purports the establishment of suitable technological packages to promote initiatives already established by smallholders and thus increase both profitability and sustainability of smallholder pig production.

Income was shown as the most important reason for pig keeping by smallholder pig keepers. Contrary to some of products of smallholder farmers that are normally produced for subsistence requirements, pigs were mainly raised for commercial purposes and thus making pig industry an important component in the system. This phenomenon has been also demonstrated by seasonal variation on extent (percent) of households' pig disposals (Fig. 22). Most pigs were sold to meet specific financial needs such as agricultural inputs, school amenities, and cash for repairing their houses, medical expenses etc. Other main classes of livestock in smallholder system such as cattle, goats, and chicken, which were commonly used for social and cultural purposes. Pig keeping is therefore characterised as small-scale market-oriented enterprise. This observation is similar to findings from studies done on smallholder pig production systems in the country and elsewhere with similar environment (Kimbi *et al.*, 2003; Lyimo, 2003; Kagira *et al.*, 2009; Ajala *et al.*, 2007; Deka *et al.*, 2007a, 2007b, 2007c).

5.1.3 Pig herd size and structure in smallholder pig production system

Herd size across study districts suggest that pig production system is small operation holdings with herd size corresponding with household resource (i.e. land, labour, capital etc) endowment. Pig keepers in Mbozi district had larger mean herd size than their counterparts in Mbeya rural, implying not only geographical variation but also socio-economic differences between the two districts, which pose interactive effects on herd size differences. Majority of pig keepers had pig herd size ranging from 1 to 4 pigs, however, district variations were observed demonstrating smallholder priority variations on similar enterprise. The observed smallholder herd size was in agreement with studies done on smallholder pig keepers in developing countries, which reported consistently small pig herd sizes. In Tanzania Kimbi *et al.* (2003) reported mean herd size of 7.2 for smallholder pig keepers in Rungwe and Mbozi districts, while, Mbaga *et al.* (2005) reported mean herd size of 7.6 per household for local pigs kept by smallholder farmers in Mbozi, Rungwe, Mbeya rural and Ileje districts of Mbeya region in Tanzania. In other African countries, Kagira *et al.* (2009) reported mean herd size of 3.6 pigs per household for smallholder pig keepers practising free-range management system in Busia district in Kenya, while, Ajala *et al.* (2007) reported mean herd size of 3.1 per household for smallholder pig production in Kaduna area of Kaduna state in Nigeria. In Asian countries Deka *et al.* (2007a, 2007b, 2007c, 2007d) reported pig herd size ranging from 1 to 6 pigs per household for smallholder practising tethering and penned pigs in districts of Dhemaji, Golaghat, Kamrup, Karbi Anglong and Kokrajhar in Assam state Northeast (NE) India.

Mean household herd size was noted to be influenced by various pig keepers' socio-economic factors such as age of household head, household size, marital status and land size of household. Higher mean herd size for pig keepers with middle age group might have been caused by the fact that this age group comprises of pig keepers with relatively good experience in pig keeping (Lyimo, 2003; Mwakasendo *et al.*, 2006), high economic status in the community (URT, 2005), and risk taking (Kagira *et al.*, 2009; Ajala *et al.*, 2007). On the other hand, it was also observed that mean herd size was higher for households with household size between seven and nine individuals. This observation might have been attributed to increased household labour force to undertake pig keeping activities, increased household expenses caused by big family size which necessitated the struggle for increased household income from pigs. In smallholder production systems household size is associated with household labour force, which is one of the most important driving factor for production (NBS, 2002). Similarly, different studies on smallholder pig keepers have positively associated household size with pig herd size (Deka *et al.*, 2007; Ajala *et al.*, 2007). Mean herd size was also observed to be low in divorced headed households which might have been caused by low socio-economic base of these households. Most of divorcees were women (most of divorced men usually re-married), and according to prevailing traditions, the divorced women loose most of important production assets such as land and capital, which are important components in pig production. In this situation, such households were only able to keep small pig herd sizes that could be manageable within their marginal socio-economic situation.

Land size was observed to have a positive influence on the pig herd size, implying the tendency of increased herd size with increased land size. Land is one of the most important resource and asset in smallholder production system (ILRI, 1995; Chawatama, *et al.*, 2005; NEPAD, 2006). Various studies have shown positive relationship between land size and household wealth (ILRI, 1995; NBS, 1993, 2002; NEPAD, 2006). According to NEPAD (2006) land was estimated to account for 42% of the agricultural capital in Sub–Saharan Africa. Based on this scenario, households with large land size were also more likely to possess a larger socio-economic base such as capital and labour which are important investment components in pig production. Thus, these households were able to maintain larger herd size than their counterparts with small land sizes. This observation was consistently similar to findings from studies on smallholder pig keepers done elsewhere (Ajala *et al.*, 2007; Deka *et al.*, 2007a, 2007b, 2007c).

Besides mean pig herd size being small, smallholder pig keepers kept strategically different pig herd structure based on their objectives and socio-economic circumstances. Most of pig keepers kept breeding sow with a mean number of one sow per household. This observation signifies the stake of pig keepers into breeding biased pig enterprise (see also section 5.3.1.1). May be in this production system keeping pigs for breeding purpose was more attractive (i.e. investment requirement and return on investment) than fattening. Moreover, the outputs from keeping breeding sows (mainly piglets) were comparatively easily marketable and/or more paying than otherwise (see section 5.3.1.1 & 5.3.1.4). Nevertheless, the proportion of households keeping breeding boars and the mean number of breeding boars per household were small. This might be one of the strategies of smallholder farmers to reduce cost, which is natural phenomenon in small-scale/peasantry agriculture. These observations were similar to findings from studies done in smallholder pig production system at Kikuyu division in central Kenya (Wabacha *et al.*, 2004), Ramotwa village in Botswana (Nsoso *et al.*, 2006) and Dhemaji district in India (Deka *et al.*, 2007), where majority of pig keepers were keeping breeding females in higher proportion to other classes of pigs. This observation was however contrary to findings from Mbulu district in Northern Tanzania (Ngowi *et al.*, 2007), Busia district in Western Kenya (Kagira *et al.*, 2009) and at Golaghat, Kamrup and Kokrajhar districts in India (Deka *et al.*, 2007) where relatively few pig keepers kept breeding sows. In Busia district different pig keepers were specialized in different pig classes, while, in Golaghat, Kamrup and Kokrajhar districts in India and Mbulu district in Tanzania majority of pig keepers kept fatteners. These observations imply that, different pig keepers practising similar production system might have different objectives and strategies of pig keeping depending on different influencing factors in their environment. Piglets, weaners, growing females, and non-castrated growing males were also among the pig classes owned by a relatively large proportion of pig keepers. Piglets were the important pig stock in smallholders for multiple options such as marketing, replacement stock, and fatteners. Most of young weaners and growers (females and non-castrated males) were sold to other pig keepers making these classes important income generator for the households (see also section 5.3.1.1).

5.1.4 Smallholder pig production systems and their classification

5.1.4.1 Characteristics and influences of different factors on distribution of smallholder pig management systems

Specific variation were revealed on pig production systems in study area, which were classified broadly into three management systems (Total confinement (TC), semi confinement (SC) and free range and herding (FRH).

Moderate number of pig keepers practised total confinement (TC) management system across districts. However, the system was more commonly practised in Mbeya rural than in Mbozi district. This finding implied differences between these two districts on the background of pig keeping which might have been attributed among other factors to geographical location, agro-ecology, and prevailing agricultural systems

Level of education was an important factor, which influenced pig keepers to practise different pig management system. Pig keepers with relatively higher education such as secondary and primary were more often practising TC than their counterparts with no formal education. This observation shows the influencing role of education in adoption of more improved management system. This might be caused by the fact that more educated pig keepers were able to take risk associated with adoption of TC system, and more informed about advantages and the managerial requirement of the system. Various scholars elsewhere have also reported the effects of education in influencing utilization of improved agricultural innovations (Appleton and Balihuta, 1998; Alene and Manyong, 2007; Tchale, 2009). These findings advocate provision of education packages as key aspect in improving adoption of improved agricultural innovation to smallholder farmers, particularly pig production innovations.

Land size was among the observed important factors influencing pig keepers to practise different pig management system. Pig keepers practising TC had significantly small mean land size compared to their counterparts practising SC and FRH. This observation implied that land has modified effects on type and extent of smallholder agricultural production especially pig production. Household land size is influenced by varying interacting factors (such as demography, socio-economic and agro-ecology) which affect land use and control including levels of intensification. In smallholder agricultural systems, level of land intensification and land protection is likely to be higher in small land sizes for the reason of maximizing agricultural outputs. In this context, pig keepers with small land sizes might have been in agricultural system with more intensified and protected land, which denied them to practise SC, and FRH pig management systems. FRH and SC pig management systems were significantly more common to pig keepers with larger land sizes, which offer room for extensive agricultural systems. Free ranging of pigs was earmarked as earlier pig keeping system and important feature in traditional pig production system in Africa (Blench, 2000; Nsoso *et al.*, 2006; Campbell *et al.*, 2006). Based on this scenario, pig management systems in some study areas were reflecting basic features of traditional pig production system. Nevertheless, the observed differences in management systems, which reflect diverse nature of agro-ecology, farming systems and socio-economic factors of study area, have demonstrated the transition of traditional pig management systems from free-range system into relative advanced SC and TC systems.

Pig herd size was also an important factor influencing pig keepers to use different pig management systems. Pig keepers with large (above four) herd sizes practised FRH more than those with small (one to four) herd sizes. Various factors such as herd size resource requirement, land size, and protection, agro-ecology and their interactions might have contributed to this observation. Herd size has effects on piggery resources investment such as shelter, labour, feeds, and feeding. The larger the herd size the higher the demand for resources and thus higher investment costs. In this situation, pig keepers with large herd sizes might have used FRH management system as a strategy of reducing investment cost. This is also supported by reasons for practising FRH indicated by pig keepers whereby reducing feeding cost was shown as important reason. Moreover, land size and protection, which is influenced by agro-ecology and farming system, might also have influenced this phenomenon. Pig keepers with larger herd sizes, would be able to practise FRH if type of agro-ecology could support farming system, which would allow the FRH practise. Locations where extensive agricultural systems are applied could provide also room for FRH to be practised than locations with intensive agricultural systems.

Other types of livestock kept by pig keepers such as local cattle and goats were among the other important factors influencing type of management systems used by pig keepers. Pig keepers with relatively larger (above two) herd sizes of cattle and or goats were 1.5 and 2.5 times, respectively, more likely practising FRH than their counterparts with none or small (less than two) herd sizes. This observation might have been caused by type of dominant agricultural system surrounding pig keepers, socio-economic context of pig keepers, and other intrinsic and extrinsic institutional factors such as marketing and extension services. Pig keepers with larger herd sizes of cattle and or goats were most likely located in areas where agricultural system can give space for grazing, which provide typical characteristics of extensive agricultural system. Since, pigs were part of this system; therefore, pig keepers might consider it rational to enlist pigs in the system. Nevertheless, other factors such pig investment cost, market availability and restriction, and level of knowledge on disadvantages of FRH, might have contributed to different adoption of pig management systems. If agricultural system gave room for FRH management system, which also reduced pig investment cost, pig keepers would be motivated to use FRH than TC. On the other hand, if pigs kept under FRH have high risk of PC infection, while, investment cost for practising FRH is low and there are no market restrictions for PC infected pigs/pork, therefore, pig keepers would be motivated to practise FRH rather than TC. Furthermore, if pig keepers have inadequate knowledge on causes and effects of PC infected pigs/pork, consequently, they would not be motivated to adopt higher cost pig management system such as TC.

5.1.4.2 Main reasons influencing pig keepers to adopt different management systems

In this study smallholder pig keepers narrated main reasons influencing them to use different pig management systems such as TC, SC and FRH. Main reasons for practising TC system were to avoid crop damage and conflicts with their neighbours. This phenomenon occurs when they failed to confine their pigs. This observation also demonstrate the community power to restrict free ranging of pigs. Another important reason for TC was to avoid or minimise diseases. This entails the level of awareness of pig keepers' on disease control measures, and roles of TC in controlling disease and other parasite infections. Improving pig security against thefts, accidents, killings (especially when damaged crops or other properties were involved) was also shown as important reason for TC. This observation implied that pig security had both social and monetary implication to pig keepers and surrounding community. TC of pigs has been earmarked as an important strategy for control of PC infection (Sarti and Rajshekhar, 2003; Kyvsgaard *et al.*, 2007; Ngowi *et al.*, 2007, 2008). However, very few (5.5 %) pig keepers said they were practising TC as strategy of avoiding/controlling PC infection. This observation entails the inadequate information to pig keepers on the causes and effects of PC.

On the other hand, feed supplementation, feeding reduction, and watering cost were shown as main factors influencing the adoption of SC and FRH management systems of pigs. Pig feeds and feeding present about 55 to 85 % of the total costs of pig production (Pond and Maner, 1974). In this context, pig keepers used different strategies to minimise investment costs. SC and FRH were among the imperative options in the study area; however, districts variations were observed and discussed (see section 5.1.3.1). SC and FRH systems were relatively popular among pig keepers due to minimum inputs required for a given return on their investment. This observation agrees with findings reported by Lekule and Kyvsgaard (2003) on traditional small-scale pig system in the tropics, Nsoso *et al.* (2006) in traditional management systems of indigenous pigs in Botswana, and Kagira *et al.* (2009) in free-range pig production system in Western Kenya.

Improving performance and exercising pigs were also shown as important reasons for practising SC and FRH systems. According to pig keepers practising TC during wet season and SC and/or FRH systems during dry season, the improved growth and reproductive performance of pig were manifested during dry seasons after releasing their pigs from TC system. Exercising of pigs was associated with nutritional background of FRH versus TC pigs. According to pig keepers' explanations, incidences of lameness and fractures were higher for confined pigs particularly pigs kept for a longer period in slatted raised floor than those kept in SC and FRH.

Although, most of pig keepers were associating incidences of lameness and fractures of confined pigs with lack of exercise, however, nutritional deficiencies and poor pig structures might have contributed to the outcome. In this respect, pigs kept in SC and/or FRH might have the nutritional benefits because they can access minerals and vitamins among other nutrients that have nutritional roles in pig health such as bone strength (Underwood, 1981; McDonald *et al.*, 1995; Lekule and Kyvsgaard, 2003). When pigs are kept in TC system all required nutrients, have to be provided by pig keepers. This has been considered as major challenge for practising and sustaining TC management system in smallholder pig production systems in developing countries (Verhulst, 1993; Lekule and Kyvsgaard, 2003; Deka *et al.*, 2007; Kagira *et al.*, 2009).

5.1.4.3 Pig shelter in smallholder pig management systems

Pig shelter is one of main necessity for effective pig management because pigs are adversely affected by climatic factors such as temperature, wind, and relative humidity. Proportion of pig keepers with pig shelters and types of pig shelters observed in smallholder pig keeping system signifies considerable development with regards to pig sheltering. Earthed and slatted raised floor were the main type of pig shelters used by majority of pig keepers. Moreover, earthed floor type of pig shelter was earmarked as traditional type of pig shelter while, slatted raised floor was newly introduced type of pig shelter. Types of pig shelters varied between study districts implying the existing variation between districts on the background of pig keeping (see also section 5.1.3.1). Proportion of pig keepers with earthed floor shelters were higher in Mbozi district than in Mbeya rural demonstrating the dominance of traditional pig keeping in Mbozi compared to Mbeya rural district. This was also supported by extent of use of different management systems between these two districts (see section 5.1.3.1). Slatted raised floor were more common for pig keepers in Mbeya rural than in Mbozi district, implying more adoption of newly type of pig shelters in Mbeya rural district. These observations qualify the existing variation on the background of pig keeping between these two districts that might have been attributed to differences in agro-ecology and agricultural systems.

Condition of pig shelter is important aspect in providing comfort and restricting free inlet or outlet of pigs (Lekule, 1995; FAO, WOAH and WB, 2010). Despite of possession of pig shelters by majority of pig keepers, most of the shelters were either in moderate or in weak conditions that could allow escape of pigs. Inadequate knowledge on appropriate shelters for pigs, socio-economic circumstances, and poor perception on the need of pig shelters might have contributed to this observation. This observation also revealed the contribution of conditions of pig shelters in free roaming of pigs and hence increasing risk factor for PC (see section 5.2.5). This was further verified by relationship between condition of pig shelters and escaping of pigs from their shelters. Pigs in moderate pig shelters were 2.3 times more likely to escape from their shelters than pigs kept in strong shelters, while, pigs kept in weak shelters were 7.4 times more likely to escape from their shelters than pigs kept in strong shelters. This finding agrees with findings reported by Phiri *et al.* (2003) in East and South African (ESA) region and Kagira *et al.* (2009) in Kenya whereby pigs were kept in primitive structures especially in areas where extensive pig keeping were dominant

Presence, types, and conditions of pig shelters also varied between different pig management systems. The finding demonstrated variation between different management systems in terms of importance of pig shelters and level of investment in pig shelters. The noted perception differences among pig keepers using different pig management systems on the importance of pig shelters might have been attributed to differences of their background in pig keeping, levels of knowledge of pig keeping, existing agricultural system and market incentives. Pig keepers whose experience in pig keeping was dominated by extensive systems including FRH system, might perceive shelters to be of low importance. Similarly, pig keepers with inadequate knowledge of pig husbandry, were also likely to give low priority to good shelters. Likewise, if the use of pig shelters had an added positive effect on pig herd productivity and consequently improved pig marketing value, then the added extra returns would be an incentive to pig keepers and thus their perception on the importance of pig shelter might be higher. These findings were consistent with findings from other scholars whereby background experience, level knowledge, and innovation incentive(s) and productivity were related to either positive or negative perception (Farouque and Takeya, 2007; Banjo *et al.*, 2010*)*

Different levels of investment between TC, SC, and FRH systems in respect to pig shelters were noted. Level of shelter investment was comparatively higher for pig keepers practising TC system because all pig keepers practising TC had shelters. Most of their shelters were slatted raised floor with comparatively stronger conditions. On the other hand, pig keepers practising FRH system had lower level of investment because about 35 % had no pig shelters. While, for those with pig shelters most of them were of traditional type and only few (18 %) of them were in strong conditions. Furthermore, pig keepers practising TC system mostly used concrete floor types of pig shelters. This type of shelters requires relatively higher level of initial investment in terms of capital and labour than the rest. Similar differences were observed on the sources and types of building materials used for erecting pig shelters in different pig management systems. Majority of pig keepers practising TC system obtained their building materials mainly timber off-cuts by purchasing them from their villages or outside villages. Majority of pig keepers practising SC and FRH obtained their building materials mainly tree and bamboo poles freely either from their own farms or in their villages.

5.1.5 Pig feeds and feeding practices in smallholder pig production system

Pig feeds and feeding is one of the most important aspects in pig production and most important pre-requisite for survival and productivity of any piggery enterprise (McDonald *et al.*, 2002; Smith *et al.*, 2005). Moreover, pig feeds and feeding involve the major investment required to run pig enterprise (Pond and Maner, 1974). Pig keepers in the study area were using different types of feeds and feeding strategies to ensure the performance of their pigs. Hominy meal was noted as main feed used by majority of pig keepers in most seasons of the year (hominy meal is one of major maize grain residue obtained during the processing of maize flour). Maize is the dominant crop cultivated in the study areas and usually used as main constituent of diets used by majority of people in the area. Therefore, the observed level of utilization was facilitated by its availability and prices. Moreover, according to pig keepers' views they consider hominy meal as most recommended feed for pigs. The extent of utilization of hominy meal was relatively higher during maize harvesting and off-season period when the supply was higher. Local brew wastes and forages were identified as second important feed resources used by pig keepers in the study area. Brew wastes especially from common locally made brews; *komoni and kimpumu* were mainly obtained from brew makers and local brew bars within pig keepers' villages. The preference of local brew waste is facilitated by its availability and prices in addition of its feeding value.

On the other hand, pig keepers mainly used green succulent forages especially during wet season when their availability was high. Green forages were obtained free from pig keepers farms or neighbouring farms. Other feed resources such as sunflower seed cake and other farm by-products such as potato and banana products were used to different extents depending on their availability in the area and seasons. Sunflower seed cake was preferably used by pig keepers in Mbozi district than in Mbeya rural district because of its availability. Extent of its use was higher during crop harvest period extending to dry season when processing (threshing and oil pressing) activities and availability of sunflower seed cakes were higher. Pig keepers used other feed stuffs such as crop residues, kitchen left over's and fruits, however, big variation were observed between individual households and villages. None of the pig keepers used commercial pig feeds. These findings signify that pig keepers used different feeds and feeding strategies such as using cheap locally available feed resources to offset feeds and feeding input cost. Use of locally feedstuffs might also attributed to un-availability of commercial feeds and associated costs. This finding agrees with reported findings in Tanzania (Kimbi *et al.*, 2003; Lyimo, 2003), in Kenya (Wabacha *et al.*, 2004), in Nigeria (Ajala *et al.*, 2007; Ironkwe and Amefule, 2008), and in tropical resource poor communities (Lekule and Kyvsgaard, 2003) where cheap locally available feed resources were used as main feed resource base.

Majority of pig keepers especially in Mbozi district fed their pigs once per day. Feeding once per day might have been used as strategy of pig keepers to offset cost of feeding in terms of amount of feed and labour inputs. Moreover, the observed districts variations might have been caused by existing variation in pig management systems and knowledge on pigs' feeds and feeding aspects. Pig keepers in Mbozi districts might have adopted once feeding per day because they were also using SC and FRH that offer supplementary feed to pigs compared to their counterparts in Mbeya rural district. Majority of pig keepers adopting once daily feeding regime said they used the regime by copying from their friends, neighbours and their elders. This signifies the inadequate knowledge and extension packages on pig feeds and feeding. The type of pig ration used by pig keepers also verified this observation. Majority of pig keepers used single feed in their pig rations. Similar findings have been reported from areas where extensive smallholder pig keeping were dominant (Ironkwe and Amefule, 2008; Kagira *et al.*, 2009)

Based on the findings on feeds and feeding of pigs in smallholder systems, both quantitative and qualitative inadequate feeding was very common to most of pig keepers. Furthermore, protein and mineral are suggested to be the most critical limiting nutrients. The effects of inadequate feeding were apparently exhibited by the poor productive and reproductive performances of their pigs.

5.2 Awareness, Knowledge, Experience and Risk Factors of PC in Smallholder Pig Production Systems

5.2.1 Importance of PC among pig health problems facing smallholder pig keepers

Worm infection especially ascarids was perceived by pig keepers as the most devastating pig health problem. In addition to the high prevalence of ascarids infection in smallholder pig production, obvious/direct effects caused by ascarids infection in pigs might have also influenced the perception of farmers. Furthermore, majority of pig keepers had no worm control strategies, thus increasing ascarids burden in their pig-keeping environment. Kimbi *et al.* (2003) and Mbaga *et al.* (2005) also reported similar observations from studies done in smallholder pig keepers in Mbeya region in Tanzania. Likewise, Ngowi, (2004) reported similar observation from study done in slaughter slabs that received pigs from smallholder pig keepers in Mbulu district in Northern Tanzania. Porcine cysticercosis was ranked second among devastating diseases in smallholder pig keepers in the area. Since, PC had no conspicuous signs and direct effects on pig productivity, most of them referred to market limitations of their infected pigs as major setback of PC. The zoonotic effects of PC were not well understood by pig keepers implying inadequate knowledge on the zoonotic burden of the PC in their environment. Otherwise, the disease could have been ranked higher. According to Perry *et al.* (2002), cysticercosis ranked among the top ten zoonotic diseases/pathogens with impact on the poor in East, Central and Southern Africa region. Mange and other external parasites, and diarrhoea were also narrated as important pig health problems facing pig keepers in the study area. This observation is similar to the findings from smallholder production systems in Tanzania (Kimbi *et al.*, 2003), Kenya (Wabacha *et al.*, 2004), Nigeria (Ajala *et al.*, (2007), and India (Deka *et al.*, 2007a, 2007b, 2007c and 2007d). These observations revealed that internal and external parasites were the most important and persistent pig health problems facing smallholder pig keepers.

5.2.2 Awareness and knowledge of PC by smallholder pig keepers

Majority of pig keepers in both study districts were aware of PC. The trend of awareness increased exponentially with increasing years, which was also similar to the trend of pig keeping in study area (see section 4.1.2). The consistency of these trends implied that pig-keeping activity has an influence on imparting awareness of PC to pig keepers. In this context, level of awareness of non-pig keepers' community is expected to be low. Despite the high level of PC awareness by pig keepers in the study area, a few of them had correct knowledge on how pigs are infected. Consequently, very few of them had knowledge on PC zoonotic relationship between pigs and humans. This observation revealed inadequate knowledge on the causes and effects of PC in pig keepers. Furthermore, using pig keepers as reference population, level of knowledge in the community of non-pig keepers is anticipated to be very low. Low health education and knowledge of *T. solium* cysticercosis and taeniosis have been shown as major obstacles to practical implementation of their practical control measures (Pawlowski *et al.*, 2005b). Various studies have demonstrated the roles and influence of knowledge particularly provision of health education for controlling *T. solium* taeniosis and cysticercosis (Keilbach *et al.*, 1989; Sarti *et al.*, 1997; Ngowi *et al.*, 2007; 2008; 2009). Health education is anticipated to increase health-seeking behaviour and compliance to other interventions such as those directed to porcine and/or human chemotherapy or improved hygienic behaviour. People with inadequate knowledge on *T. solium* taeniosis and cysticercosis infection are likely to expose themselves or their pigs to sources of *T. solium* infections, such as eating un-inspected or PC infected pork and free ranging of pigs. Studies done in Honduras (Sanchez *et al.*, 1998), Zambia (Phiri *et al.*, 2002) and Tanzania (Ngowi *et al.*, 2004), demonstrate inadequate knowledge as an important risk factor for *T. solium* cysticercosis and taeniosis transmission. Similarly, in the current study, observation was made on a positive relationship between the level of education and knowledge of pig keepers on causes and effects of PC. This observation also indicates the importance of formal education in general knowledge including knowledge on specific issues such as causes and effects of PC. It also suggests the need for careful and systematic approaches during provision of health education by considering existing differences between smallholder pig keepers and between pig keepers and pig traders and even the public.

On the other hand, districts variation was observed with pig keepers in Mbozi district having significantly low level of knowledge on how pigs get infected. This variation could be attributed to differences between these districts in their pig keeping backgrounds (see section 5.1.3.1) and access to extension education.

5.2.3 Experiences of pig keepers on PC infection and existing copping strategies

It has been observed that considerable proportion of pig keepers had experience PC infections in their pig herd. Pig traders identified some of infected pigs during pig marketing process mainly through lingual inspection. The actual extent of PC infected pigs and household with infected pigs might be high than those experienced by pig keepers because of the low sensitivity of lingual inspection method used (Gonzalez *et al.*, 1990; Dorny, *et al.*, 2004; Dorny *et al.*, 2005) and the fact that not all marketed pigs were inspected for PC. In this study, it was also noted that different experiences of pig keepers on PC infection in their pigs had an influence on decision making after discovering that their pigs were infected. The observed high tendency for most of pig keepers with previous PC experience selling their PC infected pigs, demonstrate the development of coping strategies to reduce market losses in most PC endemic areas. Moreover, PC experienced households were also observed to be more equipped with techniques of dealing with PC infected pigs than those with no experience or not aware of PC in their herd.

5.2.4 Home pig slaughter, inspection, and pork utilization by pig keepers

The observed proportion and annual slaughter frequency for pig keepers practising home slaughter revealed the status of development of meat marketing industry. Most home slaughtered pigs were sold for income, ceremony, community collective work, or home consumption. Home slaughter could be attributed to different causes such as lack of official slaughterhouse facilities, inadequate, or poor extension services including meat inspection, dominancy of traditional pig production system and lack of marketing infrastructures. It has been reported that in several areas of the country including the City of Dar es salaam, slaughtering of pigs is almost exclusively a backyard operation (Airey, 1995, cited by Ngowi *et al.*, 2004). Home slaughter could also be used as coping strategy to sell PC infected pigs. Similarly, Boa *et al.* (2001) reported home slaughtering of pig in smallholder pig keepers in Iringa district in Tanzania whereby about 22 % of pig keepers practised home slaughter. Sikasuge *et al.* (2007) reported high home slaughtering of pigs in Eastern province of Zambia whereby about 98.4 % of pig keepers kept pigs for sale and home consumption. In this study, home slaughtering was more common in Mbozi districts than in Mbeya rural district suggesting the dominancy of traditional pig keeping practice, inadequate extension services, and slaughter facilities in Mbozi compared to Mbeya rural district. Home pig slaughter presents a real risk factor for PC transmission, given that the carcasses were rarely or not inspected (only 9.6 % of home slaughtered pigs were inspected using official meat inspectors). Githigia *et al.* (2005) and Kagira *et al.* (2010) also reported similar observation from Busia District in Kenya whereby majority of pig keepers practising home slaughter had never access inspection services. In this context, home pig slaughters provide potential clandestine route for selling PC infected pigs and/or consumption of PC infected pork.

5.2.5 Risk factors for PC in smallholder pig keepers households

The PC prevalence levels in the study districts were generally alarming. This is substantiated by the observed high household PC prevalence level in majority of study villages. The observed overall districts PC prevalence values were higher than those reported by other scholars from community based studies in the country (Ngowi *et al.*, 2004; Boa *et al.*, 2006). Boa *et al.*, (2006) reported pig PC prevalence of 7.6, 8.4, and 16.9 % using lingual method in Chunya, Iringa rural and Ruvuma (Songea and Mbinga) districts, respectively, in the Southern Highlands of Tanzania. Mean while, Ngowi *et al.* (2004) reported pig PC prevalence of 17.4 % using lingual method in Mbulu district in Northern Highlands of Tanzania. Besides PC differences between studied areas, the observed variations could be also caused by lingual method employed to determine PC infected pigs, which has been shown to underestimate the actual PC prevalence due to its low sensitivity (Gonzalez *et al.*, 1990; Dorny, *et al.*, 2004; Dorny *et al.*, 2005). Furthermore, in studies by Ngowi *et al.* (2004) and Boa *et al.* (2006) in Tanzania and, Sikasuge, *et al.* (2008), Krecek, *et al.* (2008) and Waiswa *et al.* (2009) elsewhere reported individual pig PC prevalence as opposed to the current study which was based on household level PC prevalence. Household as an independent farm unit possess various intrinsic characteristics that may act as protective or risk factor for transmission of PC. Nevertheless, the observed PC prevalence was also comparatively higher than that of household based PC prevalence reported by Kagira *et al.* (2010) of 9 % from free ranged pigs in smallholder farms in Busia district in Kenya and Sikasuge *et al.* (2007) of 30.2 % from rural areas of Eastern province in Zambia. On the other hand, the PC seroprevalence observed in this study was lower than 51.7 % reported by Sikasuge *et al.* (2007) from Gwembe district in Southern province of Zambia and 54.8 % reported by Krecek *et al.* (2008) from 21 villages in Eastern Cape Province, South Africa. High household PC seroprevalence demonstrate a very high endemicity of *T. solium* cysticercosis in Mbozi and Mbeya rural districts. This scenario signifies the existence of various circumstances (risk factors) which enhance the exposure of their pigs to *T. solium* eggs.

In this study, pig management systems were identified as important risk factor for PC prevalence in both study districts. Pig keepers practising SC and FRH pig management systems were 110 % more likely to have their pigs infected with PC compared to their counterparts practising TC system. This observation implied that, SC and FRH management systems, which expose pigs to roaming increase their likelihood of being infected, compared to TC management system. Extensive pig management systems have been reported by various studies from different geographical locations of Africa, Latin America, and Asia as important risk factor for transmission of *T. solium* eggs to pigs (Krecek *et al.*, 2008; Sikasuge *et al.*, 2007; Assana *et al.*, 2001; Pouedet *et al.*, 2002; Waiswa *et al.*, 2009; Pondja *et al.*, 2010; Sarti *et al.*, 1992, 1997; Sakai *et al.*, 2001; Juyal *et al.*, 2008). Extensive pig management systems (i.e. FRH and SC) when coupled with feeding behaviour of pigs (i.e. pig is a natural scavenger of faeces) and open human defecation provide good background for pigs to access human faeces with *T. solium* eggs. Similar circumstance existed in the study area and hence accounted for the observed high PC seroprevalence

Types of pig shelters have also identified as important risk factor for PC in the study area. Pigs kept on slatted raised floor had more risk (7.4 times more) of being infected than those kept on concrete floor, which have been caused by poor condition of those types of structures. Inadequate knowledge of pig keepers on how to prepare appropriate pig structures especially slatted raised floor type of pig shelters might have contributed to this observation. Majority (63.4 %) of pig structures were in poor condition, which have allowed escape of pigs. Poor pig shelters in smallholders pig-farming systems have been also reported elsewhere as practical limitation in pig husbandry (Lekule, 1995; Phiri *et al.*, 2003; Ajala *et al.*, 2007; Kagira *et al.*, 2009). In this context, possession of pig shelter was not a sufficient condition for pig confinement, rather, ability of pig shelters to restrict free outlets of pigs. This observation provides a new arena in consideration of pig structure as important risk factor, which was not well considered in previous studies.

Previous experience of PC infection in pig herd in the household was identified as an important risk factor for PC prevalence. This has been demonstrated by pig keepers with previous experiences of PC infection in their household, which were 1.6 times more likely to have PC infected pigs than their counterparts with no past PC experience were. This observation denotes the existence of other risk factor(s) in these households, which enhance the transmission of *T. solium* eggs to pigs. The existence of human tapeworm carriers in pig keepers' households with previous experience of PC is suggested as an important confounding factor that might have contributed to this observation. Human tapeworm carriers might have caused the environmental contamination with *T. solium* eggs and proglottids. Human tapeworm carriers have been demonstrated by various studies as an important (necessary) risk factor facilitating the occurrence of both porcine and human cysticercosis particularly when personal hygiene is not observed (Garcia *et al.*, 1999; Zoli *et al.*, 2003; Lescano *et al.*, 2007; Cortez-Alcobedes *et al.*, 2010). Studies done by Lescano *et al.*, (2007, 2009) showed that pigs owned by tapeworm carriers had higher (four times) PC seroincidence compared to other pigs.

Lack of and inadequate utilization of hygienic facilities and services such as latrine and safe water were shown by several scholars as primary causes of *T. solium* cysticercosis and taeniosis particularly in PC endemic areas (Sarti *et al.*, 1992; Sanchez *et al.*, 1998; Silva-Vergara *et al.*, 1998; Murrel, 2005; Lescano *et al.*, 2007; Prasad *et al.*, 2009). In the study area majority (94 %) of pig keepers' households had latrines in their households; however, PC prevalence in their households was statistically similar to those without latrines (OR=1.96, P>0.05). This observation suggests the existence of other confounding factor(s), which might have contributed to the equal PC infection levels between households with and without latrines and thus nullifying lack of latrine as risk factor for PC seroprevalence. Similar observations were also reported by Pondja *et al.* (2010) in Angonia district in Mozambique, Sarti *et al.* (1992) in Morelos, Mexico and Pouedet *et al.* (2002) in two rural communities of West Cameroon. This observation, was however, contrary to results ported by Ngowi *et al.* (2004) from Mbulu district in Northern Highlands of Tanzania, Kagira *et al.* (2010) from Busia district in Kenya and Mutua *et al.* (2007) from Teso district, Western Kenya where absence of latrine in pig keepers households were identified as important risk factor for PC.

Lack of significant association between the absence of latrines and the prevalence of PC in the households could have been caused by the fact that free roaming pigs were scavenging indiscriminately across households with and without latrines, regardless of their owners' latrine status. This situation provided equal chance of being infected. Latrine conditions and uses of latrines by those with latrines in their households might have also contributed to the outcome. Most (55.1 %) of latrines were in poor conditions or uncompleted which could therefore allow entry by free roaming pigs. Furthermore, not all household members used toilets, for example, most children under four years were not using latrines. Additionally, most people when they away from their households particularly in agricultural fields, they practised open-air defecation. These circumstances therefore, allowed randomly free roaming pigs to access faeces regardless of whether they come from households' with or without latrines.

On the other hand, different sources of water were observed to be important risk factor for PC seroprevalence in the study districts. Households accessing water from rivers and ponds were 2.1, and 4 times, respectively, more likely to have PC infected pigs in their households than their counterparts with access of tap water were. This observation suggests that, *T. solium* eggs contaminated rivers and ponds, thus demonstrating quantitative association of water from river and pond as important risk factor for PC. Contamination of rivers and ponds in this area could have been caused by open human defecation. Sakai *et al.* (2001) in Bahia State, North Eastern Brazil, also reported similar observation.

5.3 Smallholder Pig Marketing System

5.3.1 Pig marketing chain characteristics at producers' level

5.3.1.1 Pig acquisition and price characteristics by pig keepers

In this study it has been observed that majority of pig keepers acquired their pigs from other pig keepers within their own villages mainly for breeding purposes. Villages were therefore pig-marketing focal points and pig keepers were important market participants as both main pig suppliers and prominent buyers. Ajala and Adesehinwa, (2007) in Kaduna State, Nigeria and Kagira *et al.* (2009) in Busia district, Kenya, also reported similar observations. Normally, most of households in a village share closely similar environment such as sanitation background, pig husbandry/management systems, pig marketing systems, pig slaughter, inspection and pork eating behaviours that have been shown as important risk factor for PC. In this condition, pig keepers in respective villages might also have high risk of exchanging infected pigs through marketing.

Additionally, this phenomenon confined most related pig genotypes within the villages that may contribute to the inbreeding depression. This observation also qualifies breeding purpose as the focus of most of pig keepers, which is also exemplified by higher proportion of breeding sows kept by majority of pig keepers (see also section 5.3.1).

Pig keepers' households were the main place for exchange. This observation suggests that pig marketing in the study area was dominated by traditional marketing systems compared to other livestock classes such as cattle and small ruminants. The main places of exchange for these other types of livestock are in the market places particularly in primary livestock markets (URT, 1997b; URT, 2006). In most primary livestock-markets in the study area pigs were not brought in. Moreover, the few markets that allowed pigs in, did not officially recognise them as merchandise, therefore, exchange were carried out informally at peripheral points of the markets.

Majority of pigs purchased by pig keepers were weaners and growers with ages ranging from two to five months. Most of pig keepers might have preferred to sell these classes of pigs in order to avoid or reduce rearing costs. Additionally, high demand and returns attributed to higher price (TZS 1764.7 per kg live weight) of this pig age group compared to pigs with ages above five months might have contributed to the phenomenon. This was also substantiated by coefficients of regression between age groups and pig prices whereby regression coefficient were positive for pig age between two and five 5 months denoting the limits on the tendency of increased pig price with increased pig ages. On the other hand, pig keepers preferred to buy these classes of pigs because it was convenient age group to secure for breeding purposes. It was also the right age period to evaluate performance for breeding pigs. Importantly, due to economic status of smallholder pig keepers it was generally cheaper for them to buy younger pigs than older ones. After all, most pig keepers felt more satisfied in raising their own breeding herd from young stock.

In this study, it was revealed that purchasing price of live pigs were positively correlated to their live weights. This implied that pig weight was an important attribute to pig performance and market price. Moreover, coefficient of determination (R^2) on relationship between pig age and price (R^2 = 20 %) and pig live weight and price (R^2 = 59 %) demonstrated that pig live weight was a better indicator of price determination than pig age. This is substantiated by the observed tendency of the majority of pig keepers and traders using pig weight as the most important price determinant (see also section 5.3.1.2 & 5.3.1.1).

5.3.1.2 Determinants of pigs to buy and price to pay by pig keepers during the process of buying pigs

This study revealed different criteria used by pig keepers to aid decision making during the process of buying pigs. Body size ranked first among the most used and preferred criteria. Since majority of pig keepers purchased pig mainly for breeding reason, they more preferred pigs with appealing body size as criteria for pig performance. According to pig keepers' experience, good body size was also a good indicator of good mothering ability and superior genetic performance particularly for a pig bought at weaning stage. Examination of whether a pig was PC infected or not was ranked as the second important criterion suggesting that some pig keepers were also aware of PC infection and knew the strategy of avoiding purchasing infected pigs. Moreover, some of the pig keepers were situated in PC endemic areas and had to be equipped with technique(s) of avoiding the purchase of PC infected pigs. Nevertheless, variation between pig keepers and pig traders was revealed on this criterion and preferences used during the process of buying pigs. Examination for PC was ranked first by most of pig traders, while, for pig keepers it was ranked second. The proportion (28 %) of pig keepers examining pigs for PC was much smaller compared to the proportion (87.1 %) of pig traders examining pigs for PC during process of buying pigs. These differences signify knowledge and PC sensitivity discrepancy between pig keepers and pig traders. Pig keepers were inadequately equipped with knowledge of identifying infected pigs and thus creating a knowledge gap between pig keepers and traders. Additionally, the sensitivity of pig keepers to PC might be lower than pig traders, which could be caused by priority variation between them. For pig keepers it may be rational to prioritise more for production potential of pigs to maximise production, while for pig traders might have prioritised more for PC free pigs to avoid market losses. Tongue examination for PC by pig traders have been also reported in other parts of Tanzania (Boa et al., 1995 and Ngowi et al 2004), and other endemic areas (Sarti *et al.*, 1992; Onah and Chiejina, 1995; Garcia-Noval *et al,* 1996). In the observed situation, possibility of buying PC infected pigs was higher for pig keepers than pig traders.

Consequently, pig body size, healthy looking, and body length and coat colour which were used as determinants for selecting pigs to purchase were also identified as important factors determining purchasing price for pigs bought by pig keepers. Among purchasing price determinants pig body size, which reflects body weight, was noted to be the most important price determinant. This verified the importance of body size as criteria for pig performance and price. Pig breed was ranked second by pig keepers among important price determinant, with higher price value given to pigs with exotic pig traits. This finding shows the perceived importance and need for improved breeds in the study area. This could be attributed to the fact that most pigs kept in the study area were local (Mbaga *et al.*, 2005). In this situation, most of the pig keepers were interested in keeping more improved breeds and thus paying higher value with the expectation of increased productivity to their piggery enterprise. Sex of pigs was ranked third implying its potentiality as price determinant particularly in Mbozi district where female pigs had higher prices than males. This observation reflects the utility of female pig in smallholder pig system particularly in Mbozi district. Female pigs were mainly bought for breeding purposes. Notably, most of the pig keepers kept pigs particularly females for breeding reasons, thus making female pigs more valuable than males. This is also verified by smallholder pig structure (see section 5.1.3). These observations agree with the findings reported by Williams *et al.* (2006) whereby animal age, sex, breed, body condition, season of sale and market locations were found to be the most significant factors influencing short-run cattle prices in Central corridor of West Africa.

5.3.1.3 Pig disposal and off take characteristics

Most of the pig keepers disposed off their pigs through selling at farm gate, making pig keeping a market-oriented type of enterprise. Farmers' decision to sell their pigs at the farm gate direct to customers (traders and pig keepers) rather than at places/markets that are more distant could be caused by lack of market place for selling their pigs. Furthermore, lack of pig transportation facilities and desire of avoiding transaction cost that involved handling of pigs to distant market(s) might also be among the contributing factors. Ajala and Adesehinwa (2007) in Nigeria also reported similar observation. This observation is however contrary to those reported by Deka *et al.* (2007e) from smallholder pig keepers in Assam State, Northeast (NE) India whereby most pig keepers sold their pigs at daily and weekly markets located in their villages.

Monthly and seasonal variations of pigs disposed off by pig keepers demonstrate time variation in demand for income for other obligations by pig keepers and market demand for breeding, fattening, and slaughter pigs. In most parts of the study area, the December to March period was the most agricultural intense period with high demand of agricultural inputs such as labour, seed, and fertilizers. During such period, demand of cash for purchasing farm inputs was higher and thus might have caused pig keepers to sell some of their pigs for that purpose. During this period however, pig-selling prices were normally lower due to low demand for slaughter pigs. In this period, most people directed their money to agriculture activities rather than spending on food items. Additionally, low pig price in this period might be attributed to increased supply as many farmers want to sell their pigs. Pig off-take (Fig. 22) was observed to continue increasing from June on wards. This phenomenon could have been caused by increasing demand for pigs attributed to high demand and price of pigs for slaughter and rearing purposes. During this period, households cash income might have increased due to crop products sales and reduced expenditures for farm inputs, which in turn encouraged the investment in livestock sub-sector such as pigs and purchases of food items particularly pork.

Despite of pig keepers having small pig units with mean herd size of 4.4 pigs per households, the observed mean pig gross off-take per household was equal to mean number of pigs reared. This observation might have been caused by high prolificacy of piggery enterprises. The observed proportion (100 %) of pigs sold versus reared were however, higher than those reported by URT (2006) from national smallholder pig keepers whereby pigs sold were 46 % of pigs reared by pig keepers.

The annual sales rate (commercial off take rate: 152 %) observed in smallholder pig keepers in the study area demonstrate the capabilities of smallholder pig production in supplying animal protein not only in the rural areas but also in the urban areas. The observed pig off take rate was higher than reported off take rates from other main livestock classes such as cattle, sheep and goats (Chikagwa-Malunga and Banda, 2006; Negassa and Jabbar, 2008; Njombe and Msanga, 2008). Negassa and Jabbar (2008) reported annual commercial off-take rate of 7, 7 and 8 %, for cattle, sheep and goats, respectively, for smallholder farmers in highland and lowland areas of Ethiopia. Njombe and Msanga (2008) reported annual off-take rates of 29 and 28 % for sheep people directed their money to agriculture activities rather than spending on food items. Additionally, low pig price in this period might be attributed to increased supply as many farmers want to sell their pigs. Pig off-take (Fig. 22) was observed to continue increasing from June on wards. This phenomenon could have been caused by increasing demand for pigs attributed to high demand and price of pigs for slaughter and rearing purposes. During this period, households cash income might have increased due to crop products sales and reduced expenditures for farm inputs, which in turn encouraged the investment in livestock sub-sector such as pigs and purchases of food items particularly pork.

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Most of the studies have demonstrated market limitation caused by PC infected pigs (CWGP, 1993; Phiri *et al.*, 2002, 2003; Murrel, 2005; Sikasuge *et al.*, 2007; Krecek *et al.*, 2008). However, there was very limited quantitative information on effects of PC on pig production and off takes. The observed significant interaction effect between districts and PC status of households demonstrated variation of PC impact on pig off takes. This scenario implied that similar PC prevalence status might have different impacts on pig off take variables. Notably, PC infected pigs have resulted in significantly lower mean gross off take and number of pigs sold in Mbeya rural, but not in Mbozi district. This situation might have been attributed to existing districts pig market systems; limitations with regards to PC infected pigs, and extent of extension and meat inspection services. Based on these scenarios, Mbozi district might be more dominated by informal pig marketing channels that indiscriminately allow PC infected and non-infested pigs than their counterparts in Mbeya rural district. Similarly, Mbozi district might also have less extension services including pig inspection services and thus chance for marketing PC infected pigs was as equal as non-infected ones.

5.3.1.4 Age, weight and price characteristics of pigs sold by pig keepers

Mean age (10.7 ± 9.2) of pigs sold by pig keepers implied that pigs were sold at relatively lower age compared to reported mean pig market age in some smallholder systems (Ajala *et al.*, 2007; Rahman *et al.*, 2008; Kagira *et a.,l* 2009). This observation might have been contributed by the existing marketing conditions and other households' circumstances such as need for cash and objectives of keeping pigs. Lower mean age for pigs sold by pig keepers might have also been attributed to the demand of this age-group by pig keepers (see also section 5.3.1.1). Furthermore, most of the pigs were sold to traders located in rural areas that presumably had low capital and/or lack storage facilities, therefore could handle small pigs more easily than larger ones. This observation is however contrary to those reported by Kagira *et al.* (2009) in Busia district, Kenya where only 24 % of pigs were sold at age less than 9 months. The observed lower mean ages of pigs sold by pig keepers also reflected the mean live weight of 32 ± 23.8 kg for pigs sold by pig keepers. The pigs had smaller weights with respect to their ages, which suggest lower growth performance of pigs under smallholder production system. Nutritionally adequately managed pig under tropical conditions can reach a slaughter weight of 100 kg in less than eight months of age (Lekule, 1996).

As observed the relationship between age and price for pigs purchased by pig keepers' was similar to that of pigs sold by pig keepers. However, correlation (r =0.925) between price and weight of pigs sold by pig keepers was positively higher compared to the observed correlation (r = 0.74) between price and weight for pigs bought by pig keepers. This observation entails the increased positive relationship between changes in weight of pigs with changes in price for pigs sold by pig keepers, which increases the strength of weight as a good estimate/ indicator of selling price of pigs.

5.3.1.5 Access and sources of market information to pig keepers

Access to market information has been shown as one of the fundamental aspects for any market participants for achieving effective and profitable market inputs and outputs (Lee, *et al.*, 1997; Makhura, 2001, Tenge, 2005; Sheto, 2008). The observed proportion of pig keepers (18 %) having access to market information implied that pig keepers were marginalised in pig marketing system. In this circumstance, the majority of pig keepers were incapable of planning their production to match the market demand. Furthermore, most pig keepers depended on buyers (mainly pig traders) for information. This situation weakened the pig keepers' bargaining position vis-à-vis traders, thus representing a significant impediment to access better markets and better prices for their pigs. This scenario might have also contributed to high prevalence of PC as it was difficult to communicate back to producers (pig keepers) the consumers' reactions against PC infected pork. A study done by Makhura (2001) in smallholder farmers in Northern province of South Africa showed that market information promotes not only better market and better price but also improves market participation for smallholder farmers. Likewise, as noted out by FAO (1997), market information networks serve five key objectives; these include (i) the provision of basic information aimed at creating awareness among people, (ii) stimulation of demand for commodity in question, (iii) differentiating the product or services, (iv) under-lining the products' value and (v) regulating sales. Based on this finding, improvement of access to market information is suggested as important input in improving pigs' production and control of PC.

5.3.2 Pig market chain characteristics at intermediate and terminal (traders) level

5.3.2.1 Demographic and socio-economic characteristics of pig traders

Majority (94 %) of the pig traders were males denoting the dominance of males in pig trading. Various factors might have contributed to this observation including tradition and capital endowment. Traditions of most ethnic groups in the study area and some other parts of the country do not favour women to participate in livestock business particularly business involving slaughtering of animals. This is further amplified by the fact that most women lack financial capital to engage themselves in business (i.e. pig business). Low participation of women in livestock marketing in Africa have been also reported by other scholars in Africa (Kristjanson *et al.*, 2010; Musemwa *et al.*, 2010). The observed literacy level of pig traders was relatively higher than that of pig keepers which suggested that pig traders had reasonably better marketing skills than pig keepers. This position made them more competitive than pig keepers in the pig marketing environment. However, among pig traders pig transporters were more literate compared to other pig traders. This could be caused by their pig-trading environment, which required more vibrant traders in terms of literacy and capital. Type of trading, pig trading environment, and extent of competitiveness were narrated as among important factors determining demographic characteristics of a trader (Hawassi, 2006). Literacy level of pork centre operators (PCO) was similar to that of pig keepers compared to other types of traders. This observation suggests that since most of the PCO carried their business in rural areas, majority of them being also farmers from respective local population, therefore their socio-economic status were similar to that of local population. The observed literacy level of pig traders was however higher than those reported by Ajala and Adesehinwa (2007) for pig traders in Kaduna state in Nigeria with literacy level varying between 30.0 and 73.3 %

Age is also another important attribute of traders as it is associated with knowledge and experience of handling business and capital endowment. The observed mean age (33.5 ± 8.0) of pig traders was relatively young and active age period. This finding suggests that pig traders in the study areas were in economically productive age group and therefore supporting findings by Nyagori (2001) and Hawassi (2006) that most of small-scale entrepreneurs' workforce is comprised of economically active age group. This is further supported by the fact that pig trading involves extensive movement (mainly on foot) across different households in different location searching for pigs and bargaining the price, which require active body strengths. Age variations between pig traders were also observed in butchers and pig collecting agents showing higher mean ages than their counterparts. This observation was also reflected in their experience in pig trading signifying the underlying relationship between traders' age and experience in pig business. The observed pig trading mean experience (6 ± 5.3 years) was generally lower compared to reported experience of traders dealing with agro-products in smallholder systems (Nyange, 1993; Hawassi, 2006; Ajala and Adesehinwa, 2007). The differences might have been caused by variation of types of business and also the level of business establishment. Lower experience is a common phenomenon for young business. The earmarked variations on pig trading experience among pig traders, study districts and locations of pig business signifies different scenarios in the development of pig marketing system from village to urban environment. Higher experience of pig traders located in urban areas suggests that pig trading were more developed and dominant in urban than in rural areas. Pig traders in urban locations could be in a more formal and competitive environment that required them to be more established in their business compared to their counterparts located in rural areas. In this context, barriers to market entry such as capital and experience were more obvious in urban areas than in rural areas. This was further substantiated by the fact that most pig traders in urban areas obliged to posses pork trading license and payment of revenue, while, similar procedures were not common in the rural study areas. On the other hand, the observed lower experience (5.4 ± 4.7 years) of pig traders located in rural areas could have been caused by different factors including; non-consistency of pig trading whereby about 48 % of pig businesses operated infrequently or on part-time duty. Such circumstances increased the frequencies of entering and exiting the pig business thus contributing to the low experience of traders as suggested by Hawassi, (2006).

5.3.2.2 Profiles of pig traders: time allocation, types and sources of products

The observed variation of time allocated to pig business among pig traders reflects variation in the development of pig marketing systems in different locations. Pig trading was full time duty for most traders located in urban areas versus pig traders located in rural areas. This implied that pig business was more developed in urban areas which necessitated more consistent delivery of services than in rural areas. The dominance of infrequent/part time pig trading in rural areas might have been caused by variation in pork utilization between seasons and localities and extent of development of pig business. Pig business in rural areas was considered as part time duty for supplemental income as most of pig traders were primarily involved in agricultural production activities. During wet season, most households engaged in agricultural based (crop production) activities in terms of time and resources, and therefore, paid less attention to pig trading during this time. Hawassi (2006) also reported similar scenario on marketing of fruits and vegetables in Tanzania

Pig traders traded two types of pig products; live pigs and pork (fresh and cooked). Similar findings were reported in Kenya (Kagira *et al.*, 2006), Nigeria (Ajala and Adesehinwa, 2007), and India (Deka *et al.*, 2007). This observation implies that the status of pork processing/adding value was still underdeveloped. This could be due to poor marketing infrastructures such as meat handling amenities (i.e. cold chain facilities) and processing/adding value facilities and/or poor entrepreneurship in meat industry. Moreover, trading of live pigs was observed to be dominant (84.1 %) in rural compared to urban areas implying that live pigs were the primary product bought by pig traders in rural areas.

Most pig traders purchased pig products from close proximities mainly within their own villages, streets, or neighbouring villages/streets. The observed tendency could be partly caused by the need of pig traders to reduce transaction costs. Furthermore, lack of pig market places where pig traders could purchase their required supply and arrange for bulky transportation necessitated them to buy pigs from close proximity. On the other hand, this tendency might have contributed to the control of spread of diseases such as African swine fever to other areas. Nevertheless, extent of coverage by some traders such as butchers, pig transporters, and pig collecting agents during the process of buying pigs were higher. This observation suggests the prospects in the development of pig marketing; however, it also shows the risk of spread of diseases particularly PC to other places such as urban areas (i.e. Mbeya urban) and as far as other regions such as Dar es Salaam. Such finding was substantiated by pig post-mortem based PC prevalence study done in Dar es Salaam pig abattoirs by Mkupasi (2008); whereby the

PC prevalence of 6.9 % was reported for pigs supplied by pig transporters from Mbeya region. The need for promotion of pig marketing locally, regionally and even internationally is one of the most crucial cornerstones for development and sustenance of profitable smallholder piggery sector. However, any strategies for improvement need to ensure not only economic gains but also improvement in public health.

5.3.2.3 Number and price of pigs purchased by pig traders

Number of pigs purchased varied depending on type of pig traders, study districts, business area even business condition and education level of pig traders. Number of pigs purchased depend among other factors such as demand of pork, capital endowment of pig traders, volume of business and nature of pig business. In this study, mean number of pigs purchased by trader were higher in Mbeya urban than in Mbeya rural and Mbozi districts which might have been caused by higher demand and consumption of pork in Mbeya urban. Mean number of pigs purchased by pig transporters were higher compared to butchers and pork centre operators due to nature of pig business done by pig transporters. Pig transporters need economics of scale in order to reduce transportation and handling costs as suggested by Nyange, (2003) and Hawassi, (2008). Pig traders under full time business condition had higher monthly mean number of pigs purchased compared to those under part time or infrequently type of pig business. This could be attributed to the fact that full time pig business was dominant in urban areas where pig business was more developed than in rural areas (see also section 5.3.2.2). Hawassi, (2008), reported similar finding on marketing of fruits and vegetables in Tanzania. Additionally, full time traders depended on pig business as main sources of income. Notably, mean monthly number of pigs purchased by pig traders with secondary education was higher showing the influence of education on the pig business. This phenomenon could have been caused by entrepreneurial ability of pig traders with secondary education, which increased understanding of market dynamics as suggested by Omiti *et al.* (2009).

Pig purchasing prices also varied depending on district, type, and location of pig business. The observed variations might have been caused by variations in demand and supply of pig products, transport charges, and transaction costs. Higher pig purchasing price in Mbeya urban compared to Mbeya rural and Mbozi districts might have been caused by higher demand of pork as influenced by higher urban population and pork eating behaviour compared to Mbeya rural and Mbozi districts. This finding is in agreement with reviews by Delgado *et al.*, (1999) and FAO, (2005) where the increased human population, urbanization, and income growth have been suggested to increase demand for meat. Furthermore, variation in pig production environments might have caused to the outcome. Pig production in urban environment might have required more investment in terms of labour and other inputs such as feeds, which elevated the purchasing price of pigs, compared to the rural environment. This observation was also verified by higher pig purchasing prices for butchers who dominated urban areas. On the other hand, the lower pig purchasing prices in rural areas might have been caused by lower demand for pork due to lower village population and purchasing power, inefficient marketing infrastructures that increase marketing costs. Inadequate market information for pig keepers was another factor coupled with PC endemicity whereby PC infected pigs were sold at discounted price (see also section 4.3.4.3.1). Lower pig purchasing prices were experienced by pork centre operators mostly located in rural environments.

5.3.2.4 Access to and sources of market information by pig traders

Pig traders were sourcing most of market information from their fellow pig traders implying that the existing coordination between pig traders was stronger compared to the coordination among pig producers. This situation might have encouraged price collusion between pig traders against pig producers and even consumers. Consequently, the flow of market information from pork consumers via traders to pig producers was negligible. This observation revealed the inadequacy of pig/pork value chain, which dictates extensive flow of market information, active and trust relationship between market participants with long-term strategic vision as suggested by Lundy *et al.* (2004). It is notable that, there were no public marketing information systems addressing pig marketing information. This situation demonstrates the inadequate government participation in piggery sector compared to other classes of livestock such as cattle, goats, and sheep.

5.3.2.5 Determinants of selecting pigs and pork to purchase by pig traders

PC infection status as judged by lingual inspection method was ranked first by pig traders in determining which pig to purchase. This fact demonstrates the sensitivity and significance of PC in the pig business. According to pig traders' explanations, the significance of PC in their business was related to losses that might occur when the infected pig was either condemned by meat inspectors or the level of infection was too high to be easily noticed by consumers who may reject the pork or accept to buy only at reduced prices. In these scenarios, loss avoidance was an important motive by pig traders behind their strategy of lingual PC inspection before buying pigs. Similarly, observations were reported in other PC endemic areas (Phiri *et al.*, 2003; Ngowi *et al.*, 2004). The importance of PC examination as rated by pig traders was however contrary to that of pig keepers signifying disparity on PC perceptions between pig keepers and pig traders (see section 5.3.1.2).

The ranking of body size and general health status demonstrated the significance of these factors on pig marketing and profit maximization. As explained in previous sections (see section 5.3.1.1 & 5.3.1.2) body size was used as an important determinant of price. Moreover, pig traders said they could accurately estimate not only carcass weight from live pig but also the anticipated amount of money and profit. On the other hand, according to pig keepers' perceptions, general health status was linked to visual appearance and thus attraction to customers. Preference for pigs with long body length by pig traders was associated with experiences of pig traders that the carcasses of such pigs were more preferred by consumers and profitable than those from pigs with short body length. However, this trait was more preferred by pig traders located in urban and peri urban areas than in rural areas. This may be due to dominance of exotic traits in urban and peri urban areas compared to rural areas where indigenous pigs with short body length were common. Examination of inspection stamp was mainly used by pork processors as an important criterion during buying pork mainly from butchers as certification for good quality carcase for human consumption. Normally, pigs' carcases inspected by official meat inspectors particularly under official slaughter slabs were stamped as certification of a safe carcase for human consumption.

5.3.3 Market channels for pigs and pork in smallholder pig marketing system

The pig marketing chains in this study were typical smallholder agricultural production and marketing system of most developing countries whereby farmers were first link selling their produces primarily at farm gate (Williams *et al*., 2006; Kabungo, 2008). The market channels for pigs and pork in most parts of the study area were mainly informally organised systems with neither centralised nor decentralised patterns. According to Mendoza (1995), most smallholders agricultural marketing chain constitute organisational system for marketing participants in either centralised system whereby the centre is occupied by wholesaler or decentralised system where producers and rural assemblers take an added responsibility. Moreover, product differentiation and market segmentation were still at infant stage constituting mainly live pigs, fresh and cooked pork targeted to instant and domestic consumers. Nevertheless, the informal markets have been reported to play an important role by providing an opportunity for small-scale producers to participate in the market despite their small capital and surpluses (Rao and Birthal, 2008). However, underdeveloped marketing systems do not provide incentives of using improved technologies including improved quality packages.

In this study pig keepers' households were the main place for exchange. Similar findings were reported by Kagira *et al.* (2009) from smallholder free range production system in Western Kenya whereby majority (89 %) of slaughtered pigs were sold to local butchers. In contrast, a study in Nigeria showed only few (3 %) of pigs were bought by traders direct from farm gate, while, 90.6 % were passed through primary markets at village level (Ajala and Adesehinwa, 2007). Whereas, a study in Assam State, NE India showed that between 70 and 90 % of pigs were sold by pig keepers as meat either directly to consumers or to local pork retailers (Deka *et al.*, 2007e). The observed differences might have been caused by variation in the development of pig marketing system infrastructures and pork demand and eating behaviour.

Despite of the absence of market place and/or rural assemblers where other middlemen could acquire pigs for further markets the observed market channels revealed inter-relationships among pig traders which ultimately increased the marketing chain to distant consumers. Each type of pig trader was observed to have a specialised business and area, such as: butchers and PP were more specialised in urban areas, while, PCO were more specialised in rural areas. However, weak and strong interrelationships among all six intermediate market participants were also observed. This situation provide potential base for improvement of pig marketing system. Nevertheless, the nature of the current marketing channels, which are highly scattered and unsupervised, create not only opportunities for the spread of PC but also creates more challenges in the control of PC through marketing interventions.

5.3.4 Pig traders PC experiences and risky behaviours influencing transmission of PC

5.3.4.1 Access to and types of pig slaughter facilities used by pig traders

Accessibility and types of slaughter facilities are among the key aspects in ensuring quality slaughter and handling of pig carcases to final consumers. Furthermore, presence of slaughter facilities in appropriate places facilitates the exercise of pig inspection and thus ensuring good quality meat for human consumption (Joshi *et al.*, 2003; FAO, 2008b). Generally, few pig traders had access to official abattoirs or slaughter slabs especially those in urban environment. The majority of traders in peri-urban and rural areas had access to private/personal slaughter slabs. Such results suggest that pig slaughter organisation and infrastructures were more developed in urban areas than the peri-urban and rural areas. This was also revealed by relatively high proportion of pig traders who slaughtered pigs at home in rural areas. Under this situation, supervision of safety and humane slaughtering of pigs might not be practical. The situation might be exacerbated by the scarcity of agricultural extension officers (particularly livestock based extension officers) that were mainly responsible for supervision of slaughtering and inspection of pigs and pork at village level. Furthermore, it was revealed that about 9.8 % of pig traders in rural areas had never accessed slaughter facilities, implying that slaughtering of pigs in this context were carried out elsewhere without considering safety measures. The observed situation with regard to accessibility and types of slaughtering facilities suggests the presence of loopholes for clandestine slaughtering of PC infected pigs and hence spreading of PC infection. Various studies have also suggested poor slaughter facilities and lack of slaughter facilities as important risky factor for PC (Mafojane *et al.*, 2003; Phiri *et al.*, 2003; Zoli *et al.*, 2003; Thomas, 2004; Sikasuge *et al.*, 2007; Krecek *et al.*, 2008)

5.3.4.2 Pork inspection services: Access and frequency of inspection

Effective pig/pork inspection services involve many aspects including presence of qualified inspector, well-planned and supervised slaughtering activities, and timely inspection services at each slaughter. In the study area, it was only pig traders in urban areas who had access to meat inspection services by trained meat inspectors. Conversely, considerable proportions of pig traders in rural areas had access to non-official inspectors (i.e. nominated person by village government and health officer/ nurses). This scenario suggests ineffective pig/pork inspection services particularly in rural areas. It was also revealed that, majority of pig traders in rural areas accessed inspection services from ward and village extension officers, however, the effectiveness of the services might have been lower due to scarcity and ineffectiveness of extension services versus quantity of pigs slaughtered and nature of pig slaughtering activities. Moreover, since the Tanzania Meat Inspection Act of 1993 does not include guidelines for pork inspection, pork inspectors abide by the guidelines for inspection of beef, which may be inadequate, and little attention may be given to the PC issue, therefore, leading to low detection of infected carcasses especially in PC endemic areas. The effectiveness of post-mortem inspection method in identifying PC is low depending on its thoroughness especially for pigs with low intensities of PC infection, due to the low sensitivity of the technique (Dorny *et al.*, 2004). The situation is further exacerbated by the extent of pork inspection whereby majority of pig traders in rural areas obtained pork inspection services occasionally. In this context, lack of effective meat inspection services particularly in the study rural areas present potential risky factor for PC.

5.3.4.3 The market chain as a possible risky conduit for PC infected pork to consumers.

The existing smallholder market chain with exception of most affiliated parties such as pig keepers as seller and pig traders as buyers, provide no other space for a third party who or which can provide quality monitoring of pigs transacted on the first place. From the first stage, the market chain becomes wider involving various channels with different PC risky conduits. Risky conduits were mainly associated with the dominance of informal marketing system (most of operations are carried out in the households), lack of defined pig handling systems particularly during transportation, inadequate coordinated slaughter and inspection services, and increased pork use. In this situation, the effectiveness of PC monitoring is very low due to presence of many loopholes for clandestine pig marketing and thus high risky for PC. Additionally, since pig traders had vast experience in understanding PC infected pigs, more sensitive to profit maximization and more informed about clandestine routes and techniques for selling infected pigs, therefore, the possibility of selling infected pigs was more obvious. Nevertheless, it is assumed that the channels involving official meat inspection, which were dominant in urban areas, had lower risky for PC because the inspection services were more organised and frequently done. On the other hand, other channels which involved home slaughter, villages and private slaughter slabs and slaughters done in local bars, which were observed to be dominant in rural areas, had higher risk conduit for PC however at varying magnitude. High PC risk is associated with inadequate meat inspection services whereby meat inspection services were frequently accessible to only about 33 to 63 % of pig traders. Nevertheless, pig traders with actual access to inspection services may be lower than reported, because some of the respondents (pig traders) might have not expressed the real situation since they were well informed that selling un-inspected carcases is illegal. Risk conduit was further widened in channels where there were no specific slaughter facilities due to difficulties in monitoring and supervising slaughter and inspection. Similar observations have also been reported in PC endemic areas particularly in rural area (CWGP, 1993; Thomas, 2004; Murrel, 2005; Sikasuge *et al.*, 2007) where pig marketing were dominated by informal channels associated with poor slaughter facilities and inspection services.

5.3.4.4 Awareness, knowledge and sources of information about PC by pig traders

All pig traders were aware of PC, signifying higher level of awareness compared to pig keepers. Higher level of awareness might have been caused by the nature of their business whereby awareness was used as important strategy to avoid losses due to PC infected pigs. This observation was substantiated by the observed relationship between pig business and PC awareness whereby pig business had a positive influence on awareness of PC by pig traders. The observed scenario also suggest that other peoples who neither kept pigs nor engaged in pig business might have a low awareness of PC. The observed positive correlation between type of pig business and period pig traders got awareness of PC suggest that different types of pig business had different PC challenges. In this situation, those with more challenges were earlier informed about PC than those with fewer challenges.

The observed lower level of awareness and knowledge on zoonotic relationship between PC infected pig/pork and human being demonstrates not only inadequate knowledge on causes and effects of PC, but also deficiency in extension and research systems in dissemination of appropriate information and knowledge to specific stakeholder such as pig keepers, traders, pork consumers and even general public. This suggestion is evidenced by sources of information about PC to pig keepers whereby only 31.4 % accessed information from extension officers. Inadequate knowledge on zoonotic relationship between PC infected pig/pork and taeniosis in humans was reported elsewhere such as Cameroon (Shey-Njila *et al.*, 2003), Zambia (Sikasuge *et al.*, 2007), Kenya (Kagira *et al.*, 2010), and Mozambique (Pondja *et al.*, 2010). Nevertheless, the level of awareness and knowledge on zoonotic relationship between PC infected pig/pork and humans for pig traders were higher than that of pig keepers.

This situation might have been caused by variation in nature of their enterprise and level of education. The observed low level of awareness and knowledge provide potential risk factor for PC because some of pig traders might engage into unhealthy risk behaviours unknowingly or strategically to maximise profit.

5.3.4.5 PC challenges among pig traders and existing coping strategies

Various techniques used by pig traders in identifying PC infected pigs demonstrated not only development of mitigation mechanisms to avoid market losses but also PC endemicity in respective areas. Moreover, some pig traders used inhumane techniques such as incision of masseter muscles of live pigs for that purpose. On the other hand, different experiences of pig traders with cases of PC infected pigs in their pig business were noted. The observed higher level of cases for PCO implies higher PC prevalence in rural areas because most of PCO carried their pig/pork business in rural areas. Other pig traders such as butchers, PT and PCA had also encountered reasonable number of PC cases, which were associated with their extent of coverage during the process of buying pigs. In this respect, pig traders with extended coverage of buying pigs have encountered more cases suggesting that they visited many villages including PC endemic villages to buy pigs. In this situation, pork consumers in other locations with low to nil PC prevalence were also at risk of being infected. Additionally, based on this study it is assumed that the level of awareness and knowledge on PC and its zoonotic potential is very low in pork consumers and the general public. In this respect, given the current levels of pork inspection, dominance of informal pig marketing systems and presence of various pig and pork marketing channels gave room for clandestine pork marketing, therefore, pork consumers are less protected and thus pig traders may take the advantage of selling infected pork without consumers knowledge. Moreover, pig traders used various techniques, which they used to sell PC infected pork. This observation evidenced the extent of development of coping mechanism of avoiding loss due to pork condemnation and/or profit maximization by buying PC infected pigs at discounted prices and sell pork at normal prices.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

The study provides empirical evidence aimed at establishing basic information on smallholder pig production and marketing in relation to PC in Tanzania. Specifically, the study (i) characterized smallholder pig production systems (ii) identified and characterized smallholder pig marketing systems, and (iii) evaluated risk factors and behaviours enhancing transmission of PC in smallholder pig production and marketing systems. This chapter therefore, presents conclusions of the study and recommendations are made with a view to improve smallholder pig production and marketing systems and provide a basis for an appropriate and sustainable control of PC.

6.1 Conclusions

6.1.1 Characteristics of smallholder pig production systems

i. Demographic and socio-economic characteristics of smallholder pig keepers revealed that there was no little deviation of smallholder pig keepers from general smallholder agricultural households. However, the observed low illiteracy level and household age provide potential opportunities for improving pig productivity if smallholder pig keepers are provided with suitable innovations.

ii. The study revealed the coexistence of interactions of agricultural sub-systems such as crop-crop, crop-livestock, livestock-livestock, farm-household, and farm-off farm activity components. This observation qualifies for mixed crop-livestock system as key economic base in smallholder pig production system. Mixed farming systems provide pig keepers with opportunity to diversify risk from a single commodity, to use resources such as labour and land more efficiently, to have several sources of capital and cash for multiple uses and therefore increased means for sustaining their livelihood.

iii. Pig production in smallholders system is invariably a small-scale enterprise. Despite being small-scale, production is primarily market-oriented and contributes considerably to livelihood objectives including generating income, accumulating capital and providing a low-cost source of meat particularly in rural areas.

iv. Smallholder pig keepers are keeping pigs under specified types of management systems that are vary with time (temporal) and space (spatial). Traditional management systems continue to dominate production systems and are invariably influenced by varying factors such as season of the year, location (districts) and some of socio-economic factors for example, education status, land size and pigs, goats and cattle herd sizes and chicken herd size.

v. Prevailing smallholder pig production system depends mainly on local inputs such as feeds, pig shelter materials, and labour of low opportunity cost within and surrounding the household.

vi. Pig keepers used different locally available feed resources and feeding strategies to offset feeds and feeding input cost. The effects of inadequate feeding were obviously observed in the poor productive and reproductive performances of their pigs. Therefore, quantity and quality of feeds and feeding of pigs are important factors limiting the scale and efficiency of smallholder pig production.

6.1.2 Herd health problems, farmers' awareness, knowledge, experience and risk factors of PC in smallholder pig production systems

i. Pig keepers expressed market limitations of PC infected pigs as major setback caused by PC. The zoonotic effects of PC were not well articulated by pig keepers implying inadequate knowledge on causes and effects of PC and zoonotic burden of the PC in their environment.

ii. Household PC prevalence levels in both study districts were generally very high. All study villages were revealed to be infected with about 47 and 53 % of villages in Mbeya rural and Mbozi districts, respectively, having more than 49 % of their households infected. This observation suggests the persistence of risk factors in smallholders pig production environment which enhance the exposure of their pigs to *T. solium* eggs

iii. Pig management systems; SC and FRH were identified as significant risk factors enhancing PC infection. Pig keepers practising SC and FRH pig management systems, which expose their pigs to free roaming were 110 % more likely to have their pigs infected with PC compared to their counterparts practising TC system.

iv. Types of pig shelters were also identified as important risk factor for PC in the study area. Pigs kept in slatted raised floor were 7.4 more likely to be PC infected than those kept on concrete floor. Inadequate knowledge on how to prepare this type of pig shelters is suggested as important contributing factor.

v. Pig keepers with past experiences of PC infection in their household were 1.6 times more likely to have PC infected pigs than their counterparts with no PC experience in their pigs herd. The existence of human tapeworm carriers in pig keepers' households with previous experience of PC is suggested as an important confounding factor that contributing to this observation.

vi. Water sources were identified to be important risk factor for PC seroprevalence in the study area. Households accessing water from rivers and ponds were 2.1, and 4 times, respectively, more likely to have PC infected pigs than their those accessing tap water. This observation suggests that, water from rivers and ponds were contaminated by *T. solium* eggs.

6.1.3 Characteristics of smallholder pig marketing systems

i. The main pig market sphere of smallholder pig farmers is village based as majority of pigs purchased or sold by farmers and traders were done within their respective villages. Similarly, majority of villagers obtained their pork for consumption from places located within their villages. Consumption was almost exclusively of fresh pork, the demand for which was growing quickly in rural, peri-urban, and urban areas.

ii. Commercial pig off take rate observed in smallholder pig systems was higher than off take rates reported for other main livestock classes such as cattle, sheep, and goats. This observation demonstrates the potential of smallholder production system of supplying animal protein in the rural and urban areas. It also signifies prospects for improving livelihood of smallholder pig keepers if appropriate interventions will be implemented.

iii. Inadequate market information to pig keepers compared to pig traders signified unbalanced marketing transaction between pig traders and producers and thus pig traders were more advantaged in dictating market prices. Lack of market information flow from pork consumers to pig producers rendered inadequate feed back information to producers (pig keepers) concerning consumers' preferences in terms of quality, quantity, and value. The observed situation provides not only limitations in access to better markets and prices for pig keepers but also contributed to high PC prevalence in the area.

iv. Pig traders' characteristics such as literacy level, age, experience, and pig-trading profiles demonstrated that each pig trader had definite characteristics specific to type and location of the business. Pig businesses were relatively more developed, competitive and dominant in urban than in rural areas. These conditions have contributed to the observed pig market chain in rural and urban areas. Moreover, these conditions provide potential prospects and background for developing future pig and pork marketing system that can ensure profitable pig production, efficient pig marketing and improved public health.

6.1.4 Risk behaviours influencing transmission of PC in smallholder pig marketing system

i. Prevailing pig marketing channels demonstrated that smallholder pig marketing systems are still dominated by informal marketing channels particularly in rural areas. Inadequate development of marketing infrastructure such as pig markets and slaughterhouses, planning and supervision of pig marketing activities were the important limiting factors. The existing market environment creates opportunities for spread of PC

ii. Inadequate and poor slaughter facilities were noted to be important risk factors influencing transmission of PC.

iii. Majority of pig traders especially in rural areas obtained pork inspection services occasionally, while, some of meat inspectors had inadequate knowledge of meat inspection. This observation identified inadequate inspection services as important risk factor for PC transmission in smallholder pig marketing systems.

iv. Majority of pig traders were aware of PC. However, few of them were aware of zoonotic relationship between PC infected pig/pork and human beings. The observed low level of awareness and knowledge provide potential risk factor for PC as some of pig traders might engage in unsafe risky behaviors.

v. This study revealed that pig traders used various techniques to sell PC infected pigs and pork. This observation suggests considerable development of coping mechanisms to avoid market losses and/or profit maximization. However, these practises provide potential risk behaviour for PC transmission

6.2 Recommendations

i. Packages aimed at improving pig productivity should take into consideration existing sub-systems integrations and livelihood approaches for improving adoption and sustainability of intended innovations.

ii. Improve pig feeds and feeding through

- Educate farmers on how best they can formulate pig ration(s) using locally available feedstuffs,
- Develop cheap feed packages based on locally feedstuffs, and promotion of feed milling units or feed suppliers selling low-cost feed supplements (e.g. incorporating fishmeal and a mineral and vitamin mixture).
- Develop and promote technologies for pig feed conservation during period of plenty to be used during period scarcity

iii. Development and sustenance of pork safety measures along pig production to marketing chain, such as

- Improvement of pig marketing infrastructures including pig markets (e.g. establishment of suitable ways of incorporating pigs into current livestock primary markets),
- Improvement of slaughter activities and facilities (e.g. develop a centralised slaughter facility at each village)
- Ensure, well-planned and supervised pig slaughter and routine inspection by qualified inspectors.
- Create pig and pork safety awareness to main pig market participants in pig market chain

iv. The strategies that have been recommended to improve value-chain and institutional capacity for hygienic pork marketing have to be designed to take into account the limits to how much consumers may be willing to pay for more quality slaughter and meat-handling practices.

v. Integrated approaches and cost-effective combination of simple interventions are recommended for effective control of *T solium* cysticercosis/taeniosis.

- Health education campaign is recommended as an initial and central strategy for other follow-up strategies. Other strategies include:
- Improvement of pig management through development and dissemination of suitable pig management packages (as economic incentive strategy),
- Development of suitable and hygiene pig marketing system (i.e. easy manageable pig slaughter facilities and procedures especially at rural areas, enough and well-trained pig inspectors).
- Chemotherapy treatment for human tapeworm infections and PC infected pigs.

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APPENDICES

Appendix 1. Checklist for PRA study; Pig keepers

S/N	Required information	Tool/Method of collection
1	Economic activities in the village and order of importance - List and ranking - Farming system (list of main crops and ranks)	- Semi structured interview (SSI) - Pair wise ranking - Pair wise ranking
2	Significance of livestock, gender roles, and priority - List type of livestock kept in the village and gender role for each livestock, - Order of importance	-SS interview + listing - Pair wise ranking
3	Significance of pig keeping and gender roles in pig keeping, - Historical trend of pig keeping in the village - Motivating factors for raising pig - Pig production/management systems: types, distribution, seasonal variability, preference, reason for preference and proportion of pig keepers practicing - Factors influencing farmers to adopt certain production system	- Historical profile - List and ranking - SSI. listing + matrix ranking - chapatti diagrams to map farmers practicing different production system - Listing and pair wise ranking
4	Pig management systems, practices - Shelters: Types of shelter, characteristic of each type, preference, proportion of farmers using, reasons for using - Diseases and parasites: prevalent diseases and parasites, distribution (space and time), class of pigs affected, mitigation mechanisms	- SSI, listing, pair wise ranking, chapatti diagram - SSI, pair wise ranking, seasonal disease/parasite calendar
5	Porcine cysticercosis: prevalence and risk factors - Awareness on porcine cysticercosis, method used to diagnose, levels of disease seriousness, proportion of pig farmers experienced the problem and mitigation mechanisms - Historical trend of the disease - Perception on the disease and sources/causes of disease - Pig slaughtering and meat inspection practice - Pig meat eating habits at household and outside household - Mitigation mechanisms for cysticercosis problem	- SSI, listing, matrix scoring - Historical profile - SSI, listing, pair wise and matrix ranking
6	Pig marketing (mapping and marketing constraints) - Pig marketing setup: Market structure & marketing channels and proportion of pig keepers and traders using - Marketing restriction and options for cysticercosis infected pig - How to market pig infested with cysticercosis and price effects	- SSI and mapping using key informants
8	Constraints limiting pig production and source effect relationship	- list constraints, pair wise ranking - develop source effect relationship for major problems using flow chart

Appendix 2. Questionnaire for cross - sectional survey: pig keepers

A. General information

i. District _______________ Ward _______________ Village __________________

ii. Agro-ecological zone_________________ Farming system __________________

iii. Date of interview ___________________ Name of enumerator _________________

B. Household characteristic

i. Name of respondent_____________________ Gender 1 = male, 2 = female _____

ii. Respondent's position in the household
1 = household head, 2 = wife of household head, 3 = child of household
4 = others (specify) ____

iii. Age of household head _____________________ (yrs)

iv. Gender of household head: 1 = male 2 = female _____________

v. Ethnic group/affiliation of household head_________________________________

vi. Marital status: 1 = married, 2 = single, 3 = widowed, 4 = divorced

vii. Education level of household head

1 = No formal education, 2 = Adult education, 3 = primary: standard 1 – 4,
4 = primary: standard 5 – 7, 5 = secondary: O - level, 6 = secondary, A-level, 7 = College/ university, 8 = others (specify) ______________________

viii. How many person live in your household __________________

ix. Household composition (household members live in the household majority of days in the week)

Age group	Number (size of age group)
Below 7 years	
7 – 14 years	
15 – 21 years	
22 – 55 years	
Above 55 years	
Total	

C. General information regarding farming

i. What is your main economic activities

S/N	Type of economic activities	Indicate (tick)	Order of importance (rank)
1.	Crop farming		
2.	Livestock keeping		
3.	Fishing		
4.	Salary employment		
5.	Business		
6.	Artisan		
7.	Charcoal making		
8.	Others (specify)		

ii. Do you have land? 1 = Yes, 2 = No **(If no go to question vi)**

iii. If yes, what type of land ownership do you have? 1 = your personal own land, 2 = hired/rented land, 3 = your friend/relative land, 4= others (specify)______________________________

iv. If it is your own personal land, how did you acquire it? 1 = inheritance, 2 = provided by village government, 3 = purchased, 4 = others (specify) ________________________

v. What is your total land holding? ____________________ (acres)

vi. If no, where do you keep your pigs? ____________________________________

vii. What are the main types crops do you grow?

Type of crop →				
Order of importance (rank)				

viii. What types of livestock do you keep?

Type of livestock	Total number	Order of importance	No sold in the last 12 months
1.			
2.			
3.			
4.			
5.			

D. Commencement and trend of pig production

i. When did you start keeping pigs? (year) ________________

ii. How is the trend of your pig numbers for the past ten years?

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Pig No										

iii. What is your purpose of keeping pigs?

Purpose	Income generation	Domestic meat production	Manure production	Cultural (i.e. dowry)	Others (specify)	
Indicate (tick)						
Order of importance						

v. What is your current pig herd size (number) ________ (crosscheck with question **C viii**)

vi. What is your current herd structure

Type	Total Number	Type of pig (ecotype/breed)*
Breeding females (Sows)		
Breeding males (boar)		
Adult non castrated males (not for breeding)		
Adult castrated males		
Adult females (not for breeding)		
Pre – weaned male piglets		
Pre – weaned female piglets		
Weaned females piglets (2 – 4 months)		
Weaned non castrated males piglets (2 – 4 months)		
Weaned castrated males piglets (2 – 4 months)		
Grower females (5 – 8 months)		
Growers males non castrated (5 – 8 months)		
Growers males castrated (5 – 8 months)		
Total		

* Type of pig (ecotype/breed): 1 = local, 2 = exotic, 3 = mixed (local & exotic), 4 = mixed (exotic & exotic), 5 = not known

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vii. Who is the owner of pig enterprise
1 = father, 2 = Mother, 3 = Children, 4 = father and mother, 3 = whole family,
5 = others (specify) ________________

viii. In your household, who is mainly responsible for the following pig production activities

Type of activity	Who is responsible (father = 1, mother = 2, children = 3, hired labor = 4, others (specify))
1. Erecting and repair of pig structures	
2. Collection of pig feeds	
3. Processing of feeds and feeding of pigs	
4. Cleaning of the pig structure	
5. Health monitoring	
6. Decision on pig treatment	
7. Disposing off the pigs (selling, slaughtering, gifts, etc)	

D. Pig acquisition

i. Usually which locations do you acquire/purchase your pigs?

1 = within the village, 2 = neighbouring villages, 3 = far villages. 4 = other districts within region, 5 = other region (specify) ________________

ii. For the past 12 months (one year) how many pig did you acquire and how?

Means of acquisitions	Tick	Number acquired	From which location(s)[1]	Which is the source(s)[2]	Place(s) of acquisition [3]	Purpose of acquisition [4]
1. Buying						
2. Gift from relatives/friends						
3. Inheritance						
4. Others (Specify)						
Total						

[1] From which location(s): 1 = within village, 2 = neighboring village, 3 = far villages, 4 = other districts within region, 5 = other region (specify).
[2] Which are the sources: 1 = pig keepers, 2 = pig traders, 3 = institute (indicate name and place), 4 = others (specify)
[3] Place of acquisition: 1 = pig keepers households, 2 = markets, 3 = others (specify)
[4] Purpose of acquisition: 1 = fattening, 2 = breeding, 3 = slaughter, 4 = others (specify)

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iii. What period (month) and particulars (age group, weight, and sex) for the pigs purchased in the past 12 months?

Pig particulars	Month											
	Jan	Feb	March	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
No purchased												
Age group*												
Estimated weight (kg)												
Sex: 1 = male, 2 = female												
Price paid (Tsh)												

Age group* = 1 = weaned piglets, 2 = grower (4 – 8 months), 3 = adult

---

iv. Which are the important examinations you normally do to a pig before buying it

A. Examination	B. Tick	C. Rank	D. Explain your preference criteria
1. Presence of cyst(s)			
2. Body condition characteristic			
a. Length of body			
b. Size of the body			
c. Colour			
3. Other health status (specify at D)			
4. Background history/records (i.e. reproductive & productivity (specify at D)			
5. Others (specify)			

v. What are the main determinants of purchasing price for pigs you have purchased?

Main price determinants	Tick	Rank	Explain your preference criteria
1. Breed/ecotype of pig			
2. Colour of the pig			
3. Health condition			
4. Sex of the pig			
5. Body condition status			
a. Fat status of the pig			
b. Size/weight			
c. Length of body			
6. Season of the year			
7. location of origin			
8. Others (specify)			

F. Pig production systems and management practices

i. How do you keep your pigs during different period of the year

Period of the year	Pig production system (Tick)						How long have you practiced (years)
	Total confinement	Semi confinement	Free range	Tethering	Herding/ grazing	Others (specify)	
1. Planting season							
2. Growing season							
3. Harvesting season							
4. Off season (dry period)							

ii. What factors/reasons motivated you to use indicated pig keeping system(s) in different period of year

Period of the year	Production system(s) used	Motivating factors/reasons for using	Advantages experienced for using the system	Disadvantages/problems experienced for using the system
1. Planting season				
2. Growing season				
3. Harvesting season				
4. Off season/dry period				

iii. What are the main feed resources do you use during different period of the year

Period of the year	Production system(s) used	Main feed resources used	Rank	Sources of feed
5. Planting season				
6. Growing season				
7. Harvesting season				
8. Off season/dry period				

G. Pig shelter (enumerator to combine physical observation of shelter and interview)

i. Do you have specific shelter for your pigs
1 = Yes, 2 = No **(if no go to question iii – iv)**

ii. If yes, what type of pig shelter are you using
1 = earthed floor, 2 = slated raised floor, 3 = slatted earthed level floor, 4 = concreted floor
5 = others (specify) ______________________

iii. If no, which factors made you not to erect shelter for your pig (s)
1.____
2.____

iv. If no, where do you keep pigs during the day? ______________, during the night?
____

v. How do you rate the importance of pig shelter
1 = very important, 2 = important, 3 = less important, 4 = not important

vi. Where do you get building material for your pig shelter? 1 = free from my farm, 2 = free within village, 3 = buying within village, 4 = free outside villages, 5 = buying outside villages

vii. Condition of pig shelter (enumerator to make assessment of floor, wall and roof of shelter with following scores:

1 = strong (highly protected can't offer free inlet and outlet of pigs), 2 = moderate (protected, however minimum effort can allow pigs out or in), 3 = weak (pig can get out and in when desires)

a. What is general condition of the shelter? ______________________
b. What is the specific condition of the floor? ______________________
c. Which material used for the floor? 1 = timber off cuts, 2 = tree/bamboo poles, 3 = cemented bricks, 4 = burned bricks, 5 = others (specify) ______________________________
d. What is the specific condition of the wall? ____________
e. Which materials used for the wall? 1 = timber off cuts, 2 = tree/bamboo poles, 3 = cemented bricks, 4 = burned bricks, 5 = others (specify) ___________________________________
f. Does a shelter have the roof? 1 = Yes, 2 = No
g. If yes, which materials used for the roof
1 = thatched grass, 2 = iron sheet, 3 = bamboo trees, 4 = others (specify) __________

viii. According to condition of shelter, do the pigs or piglets ever escape from their shelters?
1 = Yes, 2 = No

ix. If yes, how frequently? 1 = always, 2 = only occasionally, 3 = during off (dry) seasons, 4 = others (specify) ________________________________

x. According to your experience in pig keeping, which are the main limitations for erecting pig shelter?
1 ______________________________ 2. __________________________________

xi. Which are the main limitations for using pig shelter?
1 ______________________________ 2. __________________________________

H. Pig productive and reproductive performance

i. What is average performance of your pig with regards to following parameters
1. In your pig herd, how many sows farrowed for the past 12 months (this year) ___________
2. What is the total number of farrowing for that period (past 12 months) _____________
3. What is the total number of piglets borne for that period _____________
4. What was the average litter size per sow at farrowing ________ and at weaning _______
5. What was the average age of piglets at weaning ____________(months)
6. What is average age of gilts at first heat ________ (months), at first mating ________ (months), and at first farrowing _____________ (months)
7. What is average period between farrowing to next heat ______(days) or ______ (months)
8. What is average period between one farrowing to another ________________(months)

ii. Are you satisfied with your current pig productivity? 1 = Yes, 2 = No

iii. Do you want to increase pig production? 1 = Yes, 2 = No **(if no go to question v)**

iv. If yes, how do you plan to do it?
1. ____
2. ____

v. If no, why not? 1. ____
2. ____

I. Pig disposal/ off take

i. For the past 12 months, have you disposed off any pig from your herd? 1 = Yes, 2 = No

ii. If yes, what type of disposal have you done for the past 12 months (one year)

	Month											
	Jan	Feb	March	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
No disposed												
Type of disposal[1]												
Age group[2]												
Estimated weight (kg)												
Sex (1 = male, 2 = female)												
Price per pig (TZS)												
Total price (TZS)												

Type of disposal[1]: 1 = sales, 2 = gift, 3 = slaughter for home consumption, 4 = pride price, 5 = others (specify) __
Age group[2]: 1 = piglets after weaning, 2 = grower (4 – 8 months), 3 = adult

iii. Which locations do you often sell your pigs?

Location	Tick	Rank	Name of village & market	District	Region
1. Within the village					
2. Neighbour villages/markets					
3. Far villages/markets in the district					
4. Other districts within the region					
5. Other places outside the region					

iv. Whom (category of buyers) you have most sell your pigs?

Market outlets	Farmers/pig keepers	Butchers	Pig roasters	Pig retailers	Truckers	Pig collecting agent	Others (specify)
Indicate (tick)							
Rank							

v. Do you have marketing place for selling pigs? 1 = Yes, 2 = No

vi. Where do you mostly meet with buyer(s)?

1 = in your household, 2 = in the market within the village, 3 = in the market outside the village, 4 = others (specify) ____________________

vii. Have you encountered any difficulty to sell your pigs? 1 = Yes, 2 = No

viii. If yes, which are the serious difficulties you have experienced

1. ____________________
2. ____________________
3. ____________________

ix. Which are the important attributes (pigs and environmental) which determine selling prices for pigs you have sold?

Attribute	Tick	Rank	Explain briefly how it influence the price
9. Breed/ecotype of pig			
10. Colour of the pig			
11. Health condition			
12. Sex of the pig			
13. Body condition status			
d. Fat status of the pig			
e. Size/weight			
f. Length of body			
14. Season of the year			
15. location where pig is originated			
16. Others (specify)			

x. Are you satisfied with price given for your pigs? 1 = Yes, 2 = No

xi. If yes, what reasons for satisfaction? If no, what reasons for your dissatisfactions

(If Yes) Reason for satisfaction	Tick	(If No) Reason for dissatisfaction	Tick
1. Competition with other pig keepers is low		1. Competition with other pig keepers is high	
2. Quality of pig is good		2. Quality of pig is poor	
3. Reliable pig marketing		3. unreliable pig marketing	
4. Pig buyers prices are genuine		4. Cheating by buyers/buyer price not genuine	
5. Buyers are many/competitive		5. Lack of enough buyers	
6. Others (specify)		6. Others (specify)	
7.		7.	

xii. What is the price trend for the past two years? 1 = increasing, 2 = decreasing, 3 = no change

xiii. What are the important examination do traders normally do to pigs before buying them?

A. Examination	B. Tick	C. Rank	D. Explain your preference criteria
1. Presence of cyst(s)			
2. Body condition characteristic			
d. Length of body			
e. Size of the body			
f. Colour			
3. Other health status (specify at D)			
4. Background history/records (i.e. reproductive & productivity (specify at D)			
5. Others (specify)			

xiv. Do you get information about market prices for pig and types of pigs required? 1 = Yes, 2 = No

xv. If yes, how do you get the information? 1 = hear from other pig keepers, 2 = hear from pig traders, 3 = hear from mass media, 4 = others (specify) ____________________

J. Awareness, knowledge and effects of porcine cysticercosis

i. What are the major pig health problems you normally experienced in your pig herd

Type of health problem experienced	Order of importance (rank)
1.	
2.	
3.	

ii. Have you ever head or experienced about cyst in pigs? 1 = Yes , 2 = No

iii. If yes, when did you get aware of the diseases for the first time? (year) __________

iv. Briefly explain your understanding on the disease

____

v. What is the local name for the disease ____________________________

vi. Do you know how pigs get infected with cyst? 1 = Yes, 2 = No

vii. If yes, please indicate the causes of the infestation

1. ____________________________________
2. ____________________________________

viii. If yes, where did you get the information on the disease

1 = from my fellow pig keepers, 2 = extension officers, 3 = from researchers, 4 = from pig traders, 5 = others (specify)____________________

ix. Can porcine cysticercosis cause any problem to human being? 1 = Yes, 2 = No

x. If yes, briefly explain how

____

xi. How is serious the porcine cysticercosis in this village. 1 = non –existence, 2 = it is present but not serious, 3 = moderate serious, 4 = it is serious problem, 5 = I am not aware

xii. Have you ever encountered cases of cysticercosis infection in your pig herd?
1 = Yes, 2 = No, 3 = not sure

xiii. If yes, which methods do you use to understand/diagnose the infected pig
1. ____________________
2. ____________________

xiv. What do you do if you discover that your pig is infected? 1 = sell the pig, 2 = treat with ____________________, 3 = pierce the nodules, 4 = other (specify) __________ ____________________. 5 = I don't know

xv. Have you experienced any losses due to cysticercosis in your pig herd? 1 = yes, 2 = No

xvi. If yes, which are the production losses have you experienced

Year	Explain production limitation/loss encountered	Monetary value of limitation/loss in TZS

xvii. If yes, which are the marketing limitations/losses have you experienced

Year	Explain market limitation/loss encountered	Monetary value of limitation/loss in TZS

xviii. What are the mitigation mechanisms do you use to avoid or reduce the mentioned limitations
1. ____________________
2. ____________________

xix. Do you know how to prevent your pig from get infected with cyst? 1 = Yes, 2 = No

xx. If "Yes" which are the techniques involved in prevention
1. ____________________
2. ____________________

xxi. Do you know how to treat pigs which are infested with cyst? 1 = Yes, 2 = No

xxii. If yes, briefly explain how____________________
____

K. Pork slaughter, inspection, and eating behaviour

i. Do you or any member in the household use pork? 1 = Yes, 2 = No

ii. If no, what reasons made you not to use pork
____

iii. If yes, how often do you eat pork in a month and year? _____times a month, ________times a year

iv. If yes, which places do you buy pork for home consumption
1. ____________________ 2. ____________________

v. Did you ever slaughter pig at home? 1 = Yes, 2 = No

vi. If yes, how often do you slaughter pigs at home? _____ times a month, _______ times a year

vii. If "ever" how did you know weather or not it was fit for human consumption.
1 = by using our traditional inspection methods, 2 = by observing the background of slaughtered pig, 3 = by using official meat inspector, 4 = no any consideration made, 5 = others (specify) ________

viii. Within your household, which is the pork preparation method mostly preferred
1 = boiling, 2 = frying, 3 = raw, 4 = barbecue, 5 = others (specify) ____________________

ix. In this village, do you have a place(s) where someone can get prepared/cooked pork? = Yes, 2 = No

x. If 'Yes' which are place(s) located? 1.__________________ 2. __________________

xi. In these places, which are commonly pork preparation method used
1 = boiling, 2 = frying, 3 = raw, 4 = barbecue, 5 = others (specify) ________________

xii. How often, do you or member of household use pork from these places?
1 = ______ times a week, ______ times a month, _______times a year, 2 = never

L. Hygiene: extent of latrine use, water assess and use

i. Presence and use of latrine (enumerator should request permission to assess the latrine)
1 = present and being used, 2 = present but not used, 3 = the construction started, 4 = absent

ii. Type of latrine 1 = pit latrine, 2 = others (specify) ____________________________

iii. For household using latrine, the interviewer should assess the following

a) The status of walls 1= completed/strong with enough protection, 2 = incomplete/weak

b) The status of roof 1 = reasonable strong, 2 = present but week, 3 = latrine has no roof

c) Is the latrine has a closing door? 1 = Yes, 2 = No

d) Latrine base floor 1 = earthed, 2 = cemented, 2 = timber floor,

e) Presence of human faeces on the floor surface or elsewhere around household: 1 = Yes, 2 = No

f) Who are the household members allowed to use latrine; 1 = every body, 2 = parents only,
3 = male only, 4 = females only, 5 = every body except children, others (specify) ________

g) Who constructed latrine for this household 1 = father, 2 = mother, 3 = causal labourer,
4 = others (specify) ______________________________________

iv. Which are the sources of water for your household? 1 = tap water, 2 = shallow borehole,
1 = deep borehole, 4 = springs, 5 = river, 6 = others (specify) ____________________

v. Location of water source: 1 = within the household, 2 = within the village, 3 = outside the village

vi. If outside the household, what is the distance to the most used water source for your household ____(Km).

vii. Do you boil your drinking water? 1 = always, 2 = sometimes, 3 = never

viii. Under following situations how often do you wash your hand

Practice for hand washing	Most often	often	sometimes	never
2. Before eating some food				
3. before eating some food using spoon				
4. After eating some food				
5. After using latrine				

L. Institutional elements, services and accessibility

i. Do you get extensions services for your pig production activities? 1 = Yes, 2 = No

ii. If "Yes" who provides you the cervices
1 = government extension services, 2 = private extension cervices, 3 = research,
4 = my own experience, 5 = neighbouring farmers, 5 = relatives

iii. How often do you get extension service?
1 = most often (at least once per two months), 2 = often (at least once per three months),
3 = less often (at least once per six months), 4 = sometimes (at least once per year)

iv. How often are the following extension services provided to your pig enterprise

Extension cervices	Most often	often	sometimes	never
1. treatment of sick pigs				
2. construction of pig shelter				
3. management of piglets				
4. management of adults				
5. Pig feeding				
6. General control of diseases				

v. Which are main constraints limiting your pig production

Constraints	Ranking
1.	
2.	

THIS IS THE END OF THE INTERVIEW

THANK YOU VERY MUCH FOR YOUR COOPERATION

Appendix 3. Check list for longitudinal study

NAME OF THE FARMER.. F No ....
NAME OF THE VILLAGE... V No.............
NAME OF DISTRICT..DNo

Variable	Month and dates								
A. Herd dynamics		No	Age	No	Age	No	Age	No	Age
i. Herd structure **(number and age)**									
▪ Total pig herd number									
▪ Breeding females (Sows)									
▪ Breeding males (boar)									
▪ Adult non castrated males (not for breeding)									
▪ Adult castrated males									
▪ Adult females (not for breeding)									
▪ Pre – weaned male piglets									
▪ Pre – weaned female piglets									
▪ Weaned females piglets (2 – 4 months)									
▪ Weaned non castrated males piglets (2 – 4 months)									
▪ Weaned castrated males piglets (2 – 4 months)									
▪ Grower females (5 – 8 months)									
▪ Growers males non castrated (5 – 8 months)									
▪ Growers males castrated (5 – 8 months)									

iii. Interspecies composition					
▪ Local cattle					
▪ Goats					
▪ Chicken					
▪ Sheep					
iv. Farrowing particulars (1= Yes has happened, 2 = No farrowing happened)					
▪ Number of farrowing in the month					
▪ Number of parity					
▪ Total number of piglets born (alive + dead)					
▪ Number of piglets born alive					
▪ Number of males born					
▪ Number of females born					
▪ Age at 1st farrowing in case of gilts					

B. Pig acquisition	Month, Dates and respective variable particulars			
i. Have you acquired any pig this month (1 = Yes, 2 = No)				
ii. Total number acquired				
iii. Mode of acquisition (1 = buying, 2 = gift, 3 = hired, 4=oth)				
▪ Age(s) of acquired pig (Months)				
▪ Estimated weight(s)				
▪ Sex				
▪ Price paid				
iii. Location where pig was acquired: (1 = within village, 2 = neighbouring village, 3 = far village, 4 = other district, 5 = other region, 6 = other country)				
iv. From whom (1 = pig keepers, 2 = pig traders)				
v. Purposes for acquisition/buying (1= breeding, 2 = fattening, 3 = slaughter, 4 = reselling, 5 = others)				
C. Pig disposal, mortalities and disease incidences				
i. Pig disposal ▪ Have you dispose any pig this month (1 = Yes, 2 = No)				
▪ Total number disposed				
▪ Mode of disposal (1 = selling, 2 = gift, 3= hire out , 4 = slaughtered, d = others(specify)				
▪ Age of the pig				

▪ Estimated weight				
▪ sex				
▪ If sold, price paid				
Location where pig was disposed (1 = within village, 2 = neighbouring village, 3 = far village, 4 = other district, 5 = other region, 6 = other country)				
To whom pig was disposed (1 = pig keepers, 2 = pig traders)				
If pig(s) was sold, then purposes for selling (1 = school purposes, 2 = buying agric inputs, 3 = agric operations, 5 = etc)				
ii. Pig mortality. Did you experience pig mortality this month: (1 = Yes, 2 = No)				
▪ Total number of pigs died				
▪ Age class (1 = piglets, 2 = weaners, 3 = growers, ▪ 4 = adults **(specify age in the bracket)**				
▪ Sex				
▪ Reason for mortality				
i. **Disease incidences:** Have experienced any disease incidence this month (1 = Yes, 2 = No)				
▪ Total number of pigs got sick				
▪ Age class (1 = piglets, 2= weaners, 3=growers, 4= adults)				
▪ Sex (1 = male, 2 = female)				
▪ Type of diseases/ symptom(s)				
▪ Decision made (1 = treated, 2= not treated, 3 = sold, 4 =etc.)				
▪ If treated, treatment strategies used or drug(s) used				
▪ Treatment cost involved (TZS)				
▪ Effects/prognosis				
▪ Previous record for cysticercosis				
▪ Number of pig and their age and sex				
▪ H hold decision on pig/ how infected pig is handled				
▪ If shifted out of h hold, to which destination (1 = slaughtered for home consumption , 2 =sold within village, 3 = sold to neighbour village, 4 = sold to far village, 5 = sold to other district, others (specify)				
▪ New cases of cysticercosis				
▪ Age and sex of pig infected				
▪ Source of the pig				
D. Productive and reproductive performance				
i. Weaning				
Have you weaned piglets this month (1 = Yes, 2 = No)				
▪ Number of piglets weaned Vs farrowed				
▪ No males weaned vs farrowed				
▪ No of females weaned vs farrowed				
▪ Age of piglet at weaning				
▪ Estimated weight at weaning				
ii. Observed pig on heats				
▪ Total number of heat observed				
▪ Age at 1st heat in case of gilts				
▪ Days between farrowing to 1st heat for others				
iii. Observed mating/services				
▪ Total number of sows and gilts mated				
▪ Number of gilts mated				
▪ Age at 1st service in case of gilts				
▪ Days between farrowing to 1st service for sows				
▪ Cases of repeated heat after cervices				
▪ Type of mating (1 = free, 2 = supervised)				
▪ Source of boar (1 = within pig herd, 2 = from neighbour farmers, 3= from far village, 4 = others)				

▪ If outsource of boar, cost/arrangement for hiring boar				
▪ Reasons for using such boar (1= has exotic traits, 2=only available, 3 = own by friend/neighbour, 4 = its reputation, 5 = it is cheaper, 6 = others (specify)				
E. **Production systems used and associated practices**				
Types of production systems used				
Free range (have you practiced this month? (1=Yes, 2= No)				
• Pig class mainly involved (1 = all, 2 =piglets only, 3= weaners only, 4 = growers only, 5 adults only)				
• How long have you practice (days in a month)				
• Reasons for practicing				
• Advantages/gains				
• Limitations observed				
Total confinement (have you practiced this month? (1 = Yes, 2= No)				
• Pig class mainly involved (1 = all, 2 =piglets only, 3= weaners only, 4 = growers only, 5 adults only)				
• How long have you practice (days in a month)				
• Reasons for practicing				
• Advantages/gains				
• Limitations observed				
Semi confinement (have you practiced this month? (1 =Yes, 2 = No)				
• Pig class mainly involved (1 = all, 2 =piglets only, 3= weaners only, 4 = growers only, 5 adults only)				
• How long have you practice (days in a month)				
• Reasons for practicing				
• Advantages/gains				
• Limitations observed				
Tethering (have you practiced this month? (1 =Yes, 2 = No) • Pig class mainly involved (1 = all, 2 =piglets only, 3= weaners only, 4 = growers only, 5 adults only)				
• How long have you practice (days in a month)				
• Reasons for practicing				
• Advantages/gains				
• Limitations observed				
Herding (have you practiced this month? (1 = Yes, 2 = No)				
• Pig class mainly involved (1 = all, 2 =piglets only, 3= weaners only, 4 = growers only, 5 adults only)				
• How long have you practice (days in a month)				
• Reasons for practicing				
• Advantages/gains				
• Limitations observed				
ii. Feeds and feeding practices				
Type of production systems (PS) used (Refer above)				
▪ 1st PS				
▪ List of main feeds used in the month				
▪ Feeding regime used (1 = once, 2 = twice)				
▪ Ration style (1 = single, 2 = mixture)				
▪ Costs of feed used in a month				
▪ 2nd PS				
▪ List of main feeds used in the month				
▪ Feeding regime (1 = once, 2 = twice)				
▪ Costs of feed used				
▪ Feed availability (general assessment and interview) (1 = readily available, 2 = available, 3 = little, 4 = critical)				

iii. Pig housing				
Type of pig structures used (Earthed floor, slatted raised floor etc)				
House parts characteristics (roof, walls, floor etc)				
Other components (feeders and drinkers)				
Classes of pigs housed frequency				
Number and type of new pig structure constructed				
No of repairs/rehabilitation made to previous structures				
Type of repair made				

Appendix 4. Questionnaire for pig traders: butchers

A. General information

i. District ______________ Ward ______________ Village ______________
ii. Name of trader ______________________ Gender _______ (1 = female, 2 = male)
iii. Type of pig trading _____ (1 = butcher only, 2 = pork frying only, 3 = butcher & pork frying)
iv. Name of the market/location ______________________
v. Location setting of the butcher ____________ (1 = rural setting, 2 = urban setting, 3 = peri-urban)
vi. Date of interview ______________________

B. Personal information

i. What is your age ___________ yrs
ii. What is your education level?
1 = no formal education, 2 = adult education, 3 = primary: standard I - IV
4 = primary: standard I – VII, 5 = secondary: O - level, 6 = secondary: A - level
7 = College/ vocational training
iii. For how long have you practiced pig business? ______________ yrs
iv. What is the condition of your pig business? 1 = full time duty, 2 = part time duty, 3 = infrequent duty
v. Besides pig business, what other activities do you do to earn your living?
1 = crop farming, 2 = livestock farming, 3 = petty business, 4 = artisan, 5 = others (specify)
____
vi. What was the main source of initial capital for your pig business?
1 = generation from my own, 2 = credit from friends/relatives, 3 = credit from financial institution, 4 = others (specify) ______________________
vii. What is the size of your capital for running your pig business ___________ TZS

C. Sources of pigs/pork and purchasing conditions

i. Which categories of pig products do you purchase? 1 = live pigs only, 2 = pork only,
3 = both live pigs & pork, 4 = others (specify) ______________________

iii. Which areas/locations do you purchase your pigs

Location	Tick	Rank	Name of village/street/market	District	Region
Within village/street					
Neighbour villages/street/markets					
Far villages/markets in the district					
Other districts within the region					
Other places outside the region					

iv. Who are the sources/suppliers of pigs/pork and number/amount purchased?

Pig suppliers	Indicate (tick)	Place/ location[2]	Amount purchased last week		Average amount bought per month	
			Pigs (No)	Pork (kg)	Pigs	Pork (kg)
1. My own farm						
2. Pig keepers						
3. Retail traders						
4. Whole sellers						
5. Others (specify)						

[2]Place/location: 1 = pig keepers/retailers households, 2 = markets, 3 = others (specify)

v. Which types and quantity of pig purchased.

Type of pig purchased	Quantity purchased last weekly	Average number purchased monthly
1. Piglets		
2. Castrated growers' males		
3. Non castrated growers' males		
4. Growers' females		
5. Mature males		
6. Mature females		
Total purchases		

vi. What are the purchasing prices for different types of pig you have purchased recently

Pig types	Growers 30 kg		Growers 60 kg		Matures 90 kg	Mature - males 90 kg	
	Females	Males	Females	Males	Females	Castrated	Non castrated
Current price							
Max price							
Min price							

vii. Which factors limit/control your quantity of pigs/pork to be purchased?
1 = availability of the pigs/pork, 2 = purchasing prices of the pigs/pork, 3 = size of your capital, 4 = amount your consumers require, 5 others (specify) ______________

viii. How well do you know about pork prices prevailing in the market? 1 = very well, 2 = not very well

ix. From whom do you get the information about market prices for pigs and quality required?
1= from other traders, 2 = from pig keepers, 3 = others (specify) ______________

x. How do you receive the information about the prices?
1 = through telephone, 2 = visit pig keepers, 3 = visit other traders, 4 = others (specify) _____
____

xi. Is there any relationship between pig quality and purchasing price 1 = Yes, 2 = No

xii. Which are the important examinations you normally do to a pig before buying it?

A. Examination	B.Tick	C. Rank	D. Explain your preference criteria
6. Presence of cyst(s)			
7. Body condition characteristic			
g. Length of body			
h. Size of the body			
i. Colour			
8. Other health status (specify at D)			
9. Background history/records (i.e. reproductive & productivity (specify at D)			
10.Others (specify)			

Which are the important attributes, which determine purchasing price for pigs you have purchased?

B. Attribute	Tick	Rank	Explain briefly how it influence the price
17. Breed/ecotype of pig			
18. Colour of the pig			
19. Health condition			
20. Sex of the pig			
21. Body condition status			
g. Fat status of the pig			
h. Size/weight			
i. Length of body			
22. Season of the year			
23. location where pig is originated			
24. Others (specify)			

D. Pig and pork sales, prices and criteria for prices

i. How many days in the week do you sell pigs/pork ______(days),

ii. Which days ______________

iii. In your pig business, which quantity of pigs and pork sold daily, weekly and monthly

	Daily	Weekly	Monthly
Number of pigs sold			
Live weight sold (kg)			
Carcass weight sold (kg)			

iv. In your experience, what proportion of carcass and offal weights obtained after slaughtering pig with following live weights?

Live weight	Growers 20 kg	Growers 30 kg	Growers 60 kg	Matures 90 kg	Over 100 kg
Carcass weight					
Offal weight					

v. Which types of transport do you normally use to carry your pigs?
1. from your supplier to your premise/abattoir ______________________
2. from abattoir to your butcher/retailing place ______________________

vi. How many pig butchers in this village/ street/market ______________________

vii. On average, what quantity of pigs are sold per day in this village/street/market (Number_____ kg _____)

viii. Who are the main customers/consumers of your pork (pig meat)

Pig customers	Tick	Rank	Proportion/quantity purchased per day (kg)
1. Fresh pork buyers for domestic uses			
2. Cooked/roasted pork buyers			
3. Middlemen traders (pork processors)			
4. Others (specify)			

ix. Which gadget/ device do you use to weigh pig meat for your customers? 1 = weighing scale, 2 = using hand, 3 = others (specify) ______________________

x. What are the current selling prices per kilogram of fresh pig meat ________, processed/roasted meat ___________

xi. What are the important attributes which determine selling price of pig meat

Determinant(s) of selling price	Indicate (tick)	Rank	Explain the determinant characteristics
1. Market prices of pork			
2. Purchasing price of pigs			
3. Health status of the pig/meat			
4. Quality characteristics of meat			
a. Fat/lean status of the meat			
b. Colour of the meat			
5. Location where meat is sold			
6. Others (specify)			

xii. Which quantity of pork (fresh or roasted) in terms of kilogram preferred by consumers

Amount of meat (kg)	Consumer preference (tick appropriate place)							
	Most often		Often		Sometimes		Never	
	Fresh	Roasted	Fresh	Roasted	Fresh	Roasted	Fresh	Roasted
0.25								
0.5								
1								
2								
5								

xiii. Which are the important pork quality characteristics which attract majority of your customers/consumers?

Quality characteristics	Tick	Explain the preference
1. Lean meat		
2. Fat meat		
3. Color		
4. Health condition		
5. Others (specify)		
6.		

xiv. On average, how many consumers purchase pork meat from your butcher/shop per day ________

xv. What is the trend of number of your customers/consumer during past two years? 1 = increasing, 2 = decreasing, 3 = remained constant

xvi. Which are the expenses you incur in your pig business

Cost item	Amount (TZS)	Costing criteria (per day/month/per animal etc)
1.		
2.		
3.		
4.		
Total		

E. Pig slaughtering, inspection and perceptions on porcine cysticercosis

i. Which place do you slaughter your pig for selling?
1= official slaughtering slab, 2 = official abattoir, 3 = your own made slaughtering slab, 4 = fellow traders/private slaughtering slab, 5 = others place(s) (specify) ____________

ii. Do you have meat inspector inspecting pigs before selling? 1 = Yes, 2 = No

iii. If yes, who is inspecting pork in this area? 1 = village extension officer, 2 = ward extension officer, 3 = others (specify) ____________

iv. How often was the meat inspected by a meat inspector? 1 = always done, 2 = occasionally done, 3 = never done, 4 = can not remember/ do not know

v. Which are important pig health problems which limit effective pig marketing in your area

Pig health problem	Rank
1.	
2.	

vi. Are you aware of porcine cysticercosis disease? 1 = Yes, 2 = No

vii. If yes, when did you get aware about the diseases for the first time? (year) ____________

viii. If yes, briefly explain your understanding on the disease ____________

ix. Do you know how pigs get infected with cyst? 1 = Yes, 2 = No

x. If yes , please indicate the cause of infection ____________

xi. Who gave you the information about porcine cysticercosis? 1 = extension officer, 2 = other pig keepers, 3 = pig traders, 4 = researchers, 5 = others (specify) ____________

xii. Can infected pigs cause any problem to human? 1 = Yes, 2 = No

xiii. If Yes, brief explain how ____________

xiv. Have you experienced case(s) of cysticercosis infected pigs in your pig business? 1 = Yes, 2 = No

xv. If yes, in average how many cases have you experienced monthly and yearly.
About__________ cases monthly and __________cases yearly

xvi. Have you experienced any limitations/losses owing to cysticercosis infection in your pig business?
1 = Yes, 2 = No

xvii. If yes, which are the market limitations/loss have you experienced for the past three years.

Year	Explanation of market limitation/loss encountered	Monetary value of limitation/loss in TZS
2005	1.	
	2.	
2006	1.	
	2.	
2007	1.	
	2.	

xviii. Which technique(s) do you use to identify whether the pig is infected with cysticercosis or not?
1 ____________
2. ____________

xix. Who gave you the knowledge on how to identify the cysticercosis infected pig?
1 = my fellow pig traders, 2 = extension officers, 3 = pig keepers, 4 = others (specify)______

xx. How do you rate the reliability of method you're using? 1 = very reliable, 2 = moderately reliable, 3 = less reliable, 4 = not reliable, 5 = I don't know

xxi. How often have you encountered pig infected with cysticercosis among pigs exposed for your purchases this year (number of case(s) _______ per month, _________ per year)

xxii. Under normal situations, what is your decision if you find out the pig you want to purchase is infected with cysticercosis ____________

xxiii. From your experience, pigs from which locations are most often encountered with cysticercosis?
Name of location 1.____________ District 1____________
Name of location 2.____________ District 2. ____________

xxiv. Suppose you have decided to purchase the infected pig weighing 50 kg, what proportion of price do you normally pay compared to non infected pig of the same weight ____________

xxv. For other fellow traders, in the same case, what proportion of price do they pay ____________

xxvi. What do you normally do when you find out that the pig you have already purchased is infected with cysticercosis? ______________________________

xxvii. Which are the techniques normally used to sell infected pig

____

xxviii. How do you rate awareness/knowledge of your consumers on understanding pork meat infected with cyst.

1 = highly knowledgeable, 2 = knowledgeable, 3 = moderate, 4 = few, 5 = not knowledgeable

xxix. Does pig trading in this area require any official registration to operate?

1 = Yes, 2 = No, 3 = Not aware

xxx. If yes, which are the conditions for registration? 1 ______________________
2 ______________________ 3 ______________________

xxxi. Did you manage to accomplish the required conditions and obtain the registration?

1 = Yes, 2 = No, 3 = still making follow-up

xxxii. What are the main constraints do you face in your pig business

Constraints
1.
2.

THIS IS THE END OF THE INTERVIEW
THANK YOU FOR YOUR PATIENCE THAT FACILITATES THIS WORK

Appendix 5. Questionnaire for pig traders: pork processors

A. General information

i. District ______________ Ward ______________ Village ______________

ii. Name of trader ____________________ Gender _______ (1 = female, 2 = male)

iii. Type of pig trading _____ (1 = pork frying only, 2 = butcher & pork processing/frying, 3 = others (specify)

iv. Name of the market/location ____________________

v. Location setting of the business ______________ (1 = rural setting, 2 = urban setting)

vi. Date of interview ____________________

E. Personal information

i. What is your education level?

ii. 1 = no formal education, 2 = adult education, 3 = primary: standard I – IV, 4 = primary: standard I – VII, 5 = secondary: O - level, 6 = secondary: A – level, 7 = college/ vocational training

iii. For how long have you practiced this business? ______________ yrs

iv. What is the condition of your pork business? 1 = full time duty, 2 = part time duty, 3 = infrequent duty

v. Besides pork business, what other activities do you do to earn your living?

vi. 1 = crop farming, 2 = livestock farming, 3 = petty business, 4 = artisan, 5 = others (specify)

____

vii. What was the main source of initial capital for your pork business?

1 = generation from my own, 2 = credit from friends/relatives, 3 = credit from financial institution, 4 = others (specify) ______________________________

F. Sources of meat and purchasing conditions

i. Which categories of pig products do you purchase? 1 = live pigs only, 2 = pork only, 3 = both live pigs & pork, 4 = others (specify) ______________________

vi. Which areas/locations do you purchase your pork

Location	Tick	Rank	Name of village/street/market	District	Region
Within village/street					
Neighbour villages/street/markets					
Far villages/markets in the district					
Other districts within the region					
Other places outside the region					

vii. Who are the sources/suppliers of pork and amount purchased?

Pork suppliers	Indicate (tick)	Amount purchased daily (kg)	Amount purchased last week (kg)	Average amount bought per month (kg)
1. My own butcher				
2. Other butchers				

xiii. Which factors limit/control your quantity of pork to be purchased? 1 = availability of the pork, 2 = purchasing prices of the pork, 3 = size of your capital, 4 = amount your consumers require, 5 = others (specify) ____________

xiv. What is the purchasing prices per kg of pork____________

xv. How well do you know about pork prices prevailing in the market? 1 = very well, 2 = not very well

xvi. From whom do you get the information about market prices for pork and quality required?

1= from other traders, 2 = from pork consumers, 3 = from mass media 4 = others (specify)

____

xvii. How do you receive the information about the prices?

1 = through telephone, 2 = visit consumers, 3 = visit other traders, 4 = others (specify) _____

____

xviii. Is there any relationship between meat quality and purchasing price 1 = Yes, 2 = No

xix. Which are the important examinations you normally do to pig meat before buying it?

A. Examination	Rank	Explain your preference criteria
1.		
2.		
3.		

xx. Which are the important attributes which determine purchasing price for pork you have purchased?

Attribute	Tick	Rank	Explain briefly how it influence the price
1. Colour of meat			
2. Health condition			
3. lean meat			
4. Fatty meat			
5. Others (specify)			

G. Pork sales, prices and criteria for prices

i. How many days in the week do you sell pork _____(days).

ii. Which days ____________

iii. In your pork business, which quantity of pork sold daily, weekly and monthly

	Daily	Weekly	Monthly
Quantity sold (kg)			

iv. Which types of transport do you normally use to carry your pig meat form butcher to selling location?

____

v. How many pork selling centers/shops in this village/ street/market____________

vi. On average, what quantity of pork sold per day in this village/street/market _______________ kg

vii. Who are the main customers/consumers of your pork (pig meat)

Pork customers	Tick	Rank	Proportion/quantity purchased per day (kg)
1. Fresh pork buyers for domestic uses			
2. Instant pork consumers			
3. Middlemen traders (pork processors)			
4. Others (specify)			

viii. Which gadget/ device do you use to weigh pork for your customers? 1 = weighing scale, 2 = using hand, 3 = others (specify) ________________________________

ix. What are the current selling prices per kilogram of fresh pig meat ________, processed/roasted meat ________

x. What are the important attributes which determine selling price of pig meat

Determinant(s) of selling price	Indicate (tick)	Rank	Explain the determinant characteristics
1. Market prices of pork			
2. Purchasing price of pork			
3. Health status of the meat			
4. Quality characteristics of meat			
c. Fat/lean status of the meat			
d. Colour of the meat			
5. Location where meat is sold			
6. Others (specify)			

xi. Which quantity of pork (fresh or roasted) in terms of kilogram preferred by consumers

Amount of meat (kg)	Consumer preference (tick appropriate place)							
	Most often		Often		Sometimes		Never	
	Fresh	Roasted	Fresh	Roasted	Fresh	Roasted	Fresh	Roasted
0.25								
0.5								
1								
2								
5								

xii. Which are the important pork quality characteristics which attract majority of your customers/consumers?

Quality characteristics	Tick	Explain the preference
7. Lean meat		
8. Fat meat		
9. Color		
10. Health condition		
11. Others (specify)		

xiii. On average, how many consumers purchase pork meat from your butcher/shop per day _______

xiv. What is the trend of number of your customers/consumer during past two years? 1 = increasing, 2 = decreasing, 3 = remained constant

xv. Which are the expenses you incur in your pork business

Cost item	Amount (TZS)	Costing criteria (per day/month/per animal etc)
1.		
2.		
3.		
4.		
Total		

E. Awareness perceptions and effects of porcine cysticercosis

Which are important pork health problems, which limit effective pork marketing in your area?

Pork health quality problem	Rank
1.	
2.	

i. Are you aware of porcine cysticercosis disease? 1 = Yes, 2 = No

ii. If yes, when did you get aware about the diseases for the first time? (year) ______________

iii. If yes, briefly explain your understanding on the disease

____

____

iv. Who gave you the information about porcine cysticercosis? 1 = extension officer, 2 = Pig keepers, 3 = pig traders, 4 = researchers, 5 = others (specify) ____________________

v. Have you experienced case(s) of cysticercosis-infected pigs/pork in your pork business? 1 = Yes, 2 = No

vi. If yes, in average how many cases have you experienced monthly and yearly.

About__________ cases monthly and __________cases yearly

vii. Have you experienced any limitations/losses owing to cysticercosis infection in your pork business? 1 = Yes, 2 = No

viii. If yes, which are the market limitations/loss have you experienced for the past three years.

Year	Explanation of market limitation/loss encountered	Monetary value of limitation/loss in TZS
2005	1.	
	2.	
2006	1.	
	2.	
2007	1.	
	2.	

ix. Which technique(s) do you use to identify whether the pork is infected with cysticercosis or not?

1 ____

2. ____

x. Who gave you the knowledge on how to identify the cysticercosis infected pork?

1 = my fellow pork traders, 2 = extension officers, 3 = pork traders, 4 = others (specify)______

xi. How do you rate the reliability of method you're using? 1 = very reliable, 2 = moderately reliable, 3 = less reliable, 4 = not reliable, 5 = I don't know

xii. How often have you encountered pork infected with cysticercosis among pork exposed for your purchases this year (number of case(s) _______ per month, _________ per year)

xiii. Under normal situations, what is your decision if you find out the pork you want to purchase is infected with cysticercosis ____

xiv. From your experience, pork from which locations/butchers are most often encountered with cysticercosis?

Name of location/butcher 1.__________________ District 1_________________

Name of location/butcher 2.__________________ District 2. ________________

xv. Suppose you have decided to purchase the infected pork, what proportion of price do you normally pay compared to non infected pork of the same weight ___________________

xvi. For other fellow traders, in the same case, what proportion of price do they pay ______________

xvii. What do you normally do when you find out that the pork you have already purchased is infected with cysticercosis? ____

xviii. Which are the techniques normally used to sell infected pork ________________________

xix. How do you rate awareness/knowledge of your consumers on understanding pork meat infected with cyst.

1 = highly knowledgeable, 2 = knowledgeable, 3 = moderate, 4 = few, 5 = not knowledgeable

xx. Does pork trading in this area require any official registration to operate?

1 = Yes, 2 = No, 3 = Not aware

xxi. If yes, which are the conditions for registration? 1 ____________________________

2 ________________________________ 3 ____________________________

xxii. Did you manage to accomplish the required conditions and obtain the registration?

1 = Yes, 2 = No, 3 = still making follow-up

xxiii. What are the main constraints do you face in your pork business

Constraints
1.
2.

THANK YOU FOR YOUR PATIENCE THAT FACILITATES THIS WORK

Appendix 6. Questionnaire for pig traders: retailer, transporters, and collecting agents

A. General information

vii. District ____________ Ward ____________ Village ____________
viii. Name of trader ____________ Gender ______ (1 = female, 2 = male)
ix. Name of the market/location ____________
x. Category of trader _____ (1 = trucker, 2 = retailers, 3 = pig collection agent, 4 = others (specify)) _____
xi. Date of interview ____________

H. Personal information

i. What is your area of domicile? village ________ district ________ region ________
ii. What is your age ____________ yrs
iii. What is your education level?
1 = No formal education, 2 = Adult education, 3 = primary: standard I -IV
4 = primary: standard I –VII, 5 = secondary: O- level, 6 = secondary: A- level
7 = College/ vocational training
iv. For how long have you practiced pig business ____________ yrs
v. What is the status of your pig business? 1 = full time duty, 2 = part time duty, 3 = infrequent duty
vi. Besides pig business, what other activities do you do to earn money for your living?
1 = crop farming, 2 = livestock farming, 3 = petty business, 4 = artisan, 5 = others (specify)
____
vii. What was the main source of initial capital for your pig business?
1 = generation from my own, 2 = credit from friends/relatives, 3 = credit from financial institution, 4 = others (specify) ____________
viii. What is the size of your capital for running your pig business ____________ TZS

I. Sources of purchased pigs and purchasing conditions

i. How many days per week do you trade pigs ______(days), which days ____________
ii. Which areas/locations do you purchase your pigs?

Location	Tick	Rank	Name of village/street/market	District	Region
1. Within village/street					
2. Neighbour villages/streets/markets					
3. Far villages/markets in the district					
4. Other districts within the region					
5. Other places outside the region					

iii. Who are the sources/suppliers of pigs and quantity purchased?

Pig suppliers	Indicate (tick)	Place/ location[2]	Number of pigs bought last week	Average number of pigs bought per month
1. Pig keepers				
2. Retail traders				
3. Whole sellers				
4. Others (specify)				

[2]Place/location: 1 = pig keepers/retailers households, 2 = markets, 3 = others (specify)

iv. Which types and quantity of pig purchased.

Type of pig purchased	Quantity purchased last weekly	Average number purchased monthly
1. Piglets		
2. Castrated growers' males		
3. Non castrated growers' males		
4. Growers' females		
5. Mature males		
6. Mature females		
Total purchases		

v. Which are the purchasing prices for different types of pig you have purchased recently

Pig types	Growers 30 kg		Growers males 60 kg		Matures 90 kg	Mature - males 90 kg	
	Females	Males	Females	Males	Females	Castrated	Non castrated
Current price							
Max price							
Min price							

vi. Is there any relationship between pig quality and purchasing price 1 = Yes, 2 = No
vii. Which are the important examinations you normally do to a pig before buying it?

A. Examination	B. Tick	C. Rank	D. Explain your preference criteria
i. Presence of cyst(s)			
ii. Body condition characteristic			
j. Length of body			
k. Size of the body			

I. Colour			
ii. Other health status (specify at D)			
iv. Background history/records (i.e. reproductive & productivity (specify at D)			
v. Others (specify)			

viii. Which are the important attributes which determine purchasing price for pigs you have purchased?

Attribute	Tick	Rank	Explain briefly how it influence the price
25. Breed/ecotype of pig			
26 Colour of the pig			
27. Health condition			
28. Sex of the pig			
29. Body condition status			
j. Fat status of the pig			
k. Size/weight			
l. Length of body			
30. Season of the year			
31. location where pig is originated			
32. Others (specify)			

ix. How well do you know about pork prices prevailing in the market? 1 = very well, 2 = not very well

x. From whom do you get the information about market prices for pigs and quality required?
1= from other traders, 2 = from pig keepers, 3 = others (specify) ________________

xi. How do you receive the information? 1 = through telephone, 2 = visit other pig traders,
3 = pig traders visit me, 4 = though mass media, 5 = visit pig keepers, 6 = pig keepers visit me,
7 = others (specify) ________________

xii. Which factors limit/control your quantity of pig to be purchased? 1 = availability of the pigs
2 = purchasing prices of the pigs, 3 = size of your capital, 4 = amount your consumers require, 5 = others (specify)
____

D. Perceptions, awareness and limitations of porcine cysticercosis in pig marketing

i. Which are important pig health problems which limit effective pig marketing in your area

Pig health problem	Rank
1.	
2.	

ii. Are you aware of porcine cysticercosis disease? 1 = Yes 2 = No

iii. If yes, when did you get aware of the diseases for the first time? (year) ________________

iv. Who gave you the information about it? 1 = extension officer, 2 = other pig keepers, 3 = pig traders, 4 = researchers, 5 = others (specify) ________________

v. If yes, briefly explain your understanding on the disease
____
____

vi. What is local name for porcine cysticercosis? ________________

vii. Do you know how pigs get infected with cyst? 1 = Yes, 2 = No

viii. If yes , please indicate the cause of infection ________________

ix. Can infected pigs cause any problem to human? 1 = Yes, 2 = No

x. If Yes, brief explain how ________________

xi. Have you experienced case(s) of cysticercosis infected pigs in your pig business? 1 = Yes, 2 = No

xii. If yes, in average how many cases have you experienced monthly and yearly.
About__________ cases monthly and __________cases yearly

xiii. Have you experienced any limitations/losses owing to cysticercosis infection in your pig business?
1 = Yes, 2 = No

xiv. If yes, which are the market limitations/loss have you experienced for the past three years.

Year	Explanation of market limitation/loss encountered	Monetary value of limitation/loss in TZS
2005	3.	
	4.	
2006	1.	
	2.	
2007	1.	
	2.	

xv. Which technique(s) do you use to identify whether the pig is infected with cysticercosis or not?
1 ________________
2. ________________

xvi. Who gave you the knowledge on how to identify the cysticercosis infected pig?
1 = my fellow pig traders, 2 = extension officers, 3 = pig keepers, 4 = others (specify)________

xvii. How do you rate the reliability of method you're using? 1 = very reliable, 2 = moderately reliable, 3 = less reliable, 4 = not reliable, 5 = I don't know

xviii. How often have you encountered pig infected with cysticercosis among pigs exposed for your purchases this year (number of case(s) ________ per month, __________ per year)

xix. Under normal situations, what is your decision if you find out the pig you want to purchase is infected with cysticercosis ______________________________

xx. From your experience, pigs from which locations are most often encountered with cysticercosis?
Name of location 1.______________________ District 1________________
Name of location 2.______________________ District 2. ________________

xxi. Suppose you have decided to purchase the infected pig weighing 50 kg, what proportion of price do you normally pay compared to non infected pig of the same weight ________________

xxii. For other fellow traders, in the same case, what proportion of price do they pay ____________

xxiii. What do you normally do when you find out that the pig you have already purchased is infected with cysticercosis? ______________________________

xxiv. How do you rate awareness and knowledge levels of your clients on pig infected with cyst?
1 = highly knowledgeable, 2 = knowledgeable, 3 = moderate, 4 = few, 5 = not knowledgeable

xxv. Which are the techniques normally used to sell infected pig? 1. ____________________
2. ______________________________ 3. ______________________________

E. Market outlets and prices

i. To whom (customers) do you sell your pigs?

Market outlets →	Farmers/pig keepers	Pig middlemen traders			Pig agent	Pig consumers
		Retailers	Butchers	Truckers		
Indicate (tick)						
Average number sold per week						
Average distance traveled (Km)						

ii. Which locations do you often sell your pigs?

Location	Tick	Rank	Name of village & market	District	Region
6. Within your village					
7. Neighbour villages/markets					
8. Far villages/markets in the district					
9. Other districts within the region					
10. Other places outside the region					

iii. Which types of transport do you normally use to carry your pig to outlet markets?
1. ____________________ 2. ____________________

iv. Which are the selling prices for different types and weight of pig you have sold recently

Pig types	Growers 30 kg		Growers males 60 kg		Matures 90 kg	Mature - males 90 kg	
	Females	Males	Females	Males	Females	Castrated	Non castrated
Current price							
Max price							
Min price							

v. What are the important attributes which determine selling price for pigs?

Attribute	Tick	Rank	Explain briefly how it influence the price
1. Breed/ecotype of pig			
2. Colour of the pig			
3. Health condition			
4. Sex of the pig			
5. Body condition status			
a. Fat status of the pig			
b. Size/weight			
c. Length of body			
6. Season of the year			
7. location where pig is originated			
8. Others (specify)			

vi. What is the trend of number of your customers during past three years? 1 = increasing, 2 = decreasing, 3 = remained constant

vii. Which are the expenses you incur in selling your pigs

Item cost	Cost incurred per each category of pig in TZS		
	Adult pig	Growers	Piglets
1 Transport			
2. Market fee			
3. Labour charge			
4. Tax			
5. Others:			
6			
Total			

viii. Does pig trading in this area require any official registration to operate? 1 = Yes, 2 = No, 3 = Not aware

ix. If yes, which are the conditions for registration?

1. ______________________ 2. ______________________

3. ______________________ 4. ______________________

x. Did you manage to accomplish the required conditions and obtain the registration?
1 = Yes, 2 = No, 3 = still making follow-up

xi. What are the main constraints do you face in your pig business

Constraints
1.
2.

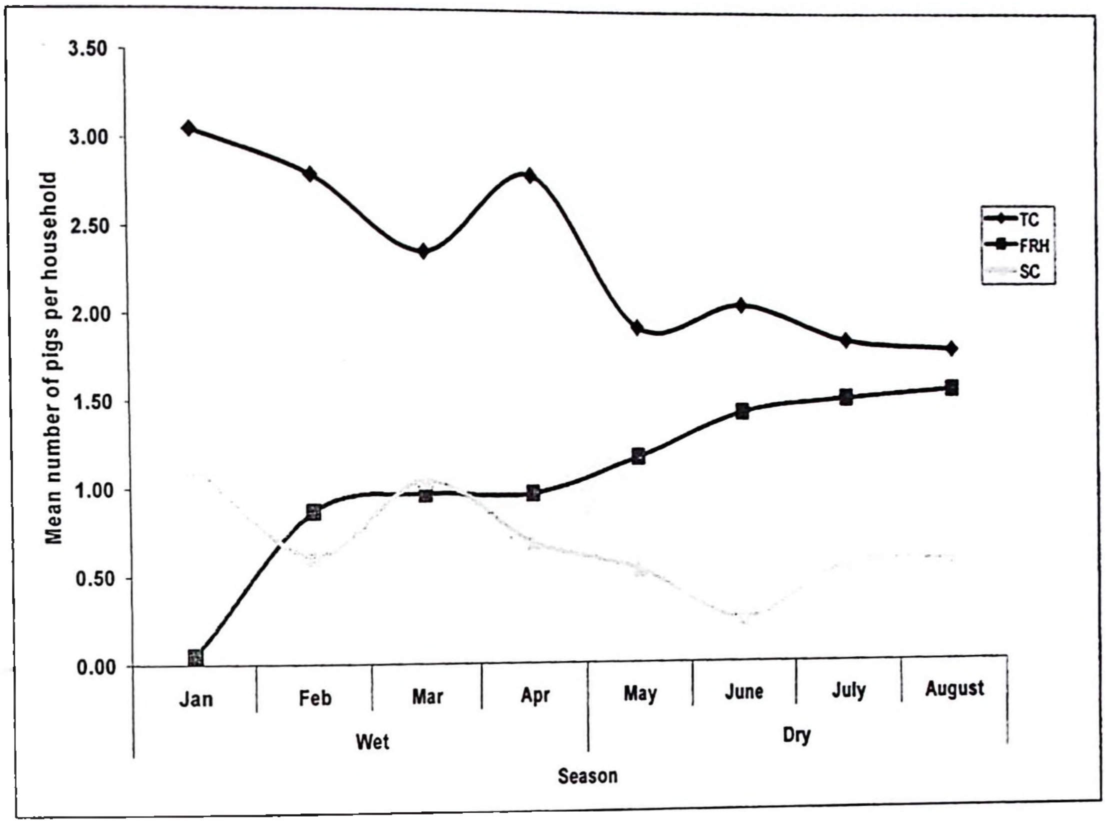
THIS IS THE END OF THE INTERVIEW

THANK YOU FOR YOUR PATIENCE THAT FACILITATES THIS WORK

Appendix 7. Types of smallholder pig management systems and distribution among different location and socio-economic factors

District	Management systems		
	Confinement	Semi-confinement	Free range/herding
Mbozi	32 (21.2)	94 (62.3)	25 (16.6)
Mbeya rural	94 (63.1)	54 (36.2)	1 (0.7)
Total	126 (42.0)	148 (49.3)	26 (8.7)
Chi square and P- value	$\chi^2 = 63.46$, P = 0.000***		
Education level of household head			
No formal education	29 (52.7)	23 (41.8)	3 (5.5)
Primary education	83 (37.1)	118 (52.7)	23 (10.3)
Secondary education	14 (66.7)	7 (33.3)	0 (0.0)
Chi square and P- value	$\chi^2 = 11.22$, P = 0.024*		
Land size (ha)			
0.01 – 2	98 (50.5)	84 (43.3)	12 (6.2)
2.01 - max	27 (26.0)	63 (60.6)	14 (13.5)
Chi square and P- value	$\chi^2 = 17.94$, P = 0.000***		
Household size (number of individuals)			
1 – 6	89 (46.8)	91 (47.9)	10 (5.3)
7 – max	37 (33.6)	57 (51.8)	16 (14.6)
Chi square and P- value	$\chi^2 = 10.04$, P = 0.007**		

Appendix 8. Variation in relative number of pigs involved in different management systems in wet and dry months of the year



Appendix 9. Prevalence of PC in pig keepers' households in the study villages in Mbeya rural district by Ag-ELISA

Village	Number of household examined	Number of household infected	Prevalence (%)
Horongo	10	9	90
Jojo	10	7	70
Idimi	10	8	80
Nsalala	10	1	10
Idugumbi	10	1	10
Idunda	10	1	10
Wimba	10	3	30
Masewe	10	6	60
Izyira	10	6	60
Kasale	10	1	10
Igoma	9	4	44.4
Mjele	10	8	80
Mshewe	10	4	40
Kimondo	10	5	50
Isuto	10	3	30
TOTAL	149	67	44.0

Appendix 10. Prevalence of PC in pig keepers' households in the study villages in Mbozi district by Ag-ELISA

Village	Number of households examined	Number of households infected	Prevalence (%)
Nandanga	10	5	50
Iyula	10	7	70
Itepula	10	3	30
Kamsamba	10	3	30
Itaka	10	4	40
Chitete	10	6	60
Nkala	10	9	90
Namole	10	6	60
Nambala	10	2	20
Sakamwela	10	7	70
Mbozi	10	1	10
Chipumpu	10	4	40
Mkutano	10	2	20
Nkangamo	10	5	50
Mpela	10	5	50
TOTAL	**150**	**69**	**45.3**

Appendix 11. Period pig traders got awareness of PC in pigs and trend of awareness among pig traders