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REGULAR ARTICLES

# Average daily gain of local pigs on rural and peri-urban smallholder farms in two districts of Western Kenya

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**Abstract** The objective of this study was to determine the average daily gain (ADG) of pigs on rural and peri-urban smallholder farms in two districts of Western Kenya, in order to establish a baseline to measure the impact of future management interventions. Average daily gain (kilograms per day) for 664 pigs weighed one, two or three times and the proportion of local and crossbreed pigs was determined. Assuming a uniform birth weight of 1 kg, ADG did not differ between pigs weighed once or twice. Overall, ADG was higher in peri-urban pigs (0.15±0.058 kg/day) than rural pigs (0.11±0.047 kg/day). Pigs at 1 to 2 months had a higher ADG than those at 3 months or 10 to 12 months and ADG was higher in crossbreed than local pigs. Over the two districts, the ADG was low (0.13±0.002 kg/day). Most (87.2 %) pigs were of local breed. Low ADG may be due to malnourishment, high maintenance energy expenditure, high parasite prevalence, disease, and/or low genetic potential. This low ADG of pigs raised on smallholder farms in Western Kenya indicates a high potential for improvement. The growth rate of pigs in Western Kenya must be improved using locally available feedstuffs to make efficient use of resources, promote sustainable smallholder pig production, and improve the livelihood of smallholder farmers.

**Keywords** Swine · Average daily gain · Indigenous pigs · Local breed · Africa · Smallholder farmer

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## Introduction

Annual consumption of pork in Sub-Saharan Africa is estimated to increase by 155 % between the years 2000 and 2030 and by 167 % across low-income countries globally (FAO 2011). Millions of pigs are raised by smallholder farmers in East Africa. In 2008, there were 3.2 million pigs in Uganda with 1.1 million households keeping on average two pigs (UBOS 2011). In 2011, 117,000 tonnes of pork were produced in Uganda and nearly 1/3 of the 10 kg of meat consumed per capita was pork (FAOSTAT). In Kenya, small-scale production is practiced by 70 % of pig producers (FAO 2012). In 2009, there were 187,000 pigs in Kenya and of these, 84,000 were raised in traditional/backyard systems (KNBS 2009). Resource-poor subsistence farmers in the tropics, raise pigs to generate income (FAO 2012). Pig keeping is attractive for several reasons: pigs require minimal inputs and labour, have high feed conversion efficiency, produce offspring in large numbers, and have short intervals between generations (Lekule and Kyvsgaard 2003; Mutua et al. 2010). Extreme poverty in Kenya can be alleviated through pig production (FAO 2012), but the productivity of pigs raised by poor farmers is low. Evidence is needed to identify and remove production constraints in order to realise the full potential benefits of pig production. The objective of this study was to determine the average daily gain (ADG) of pigs on smallholder farms in two districts of Western Kenya in order to establish a baseline ADG so that the outcome of any future interventions related to improvement of ADG can be measured.

## Materials and methods

This research was approved by the Research Ethics Board and the Animal Care Committee of the University of Guelph, the Director of Veterinary Services in Kenya, and the Board of Postgraduate Studies, University of Nairobi, Kenya. Participants gave informed consent before participating in the study. The study area and selection of farms is described in detail by Mutua et al. (2011a). Briefly, two districts in Western Province, Kenya, were selected: a peri-urban area, Kakamega District, and a rural area, Busia District. These districts were identified as areas of extreme poverty by the International Livestock Research Institute and have a high prevalence of pig farming (Thornton et al. 2002; Mutua et al. 2010). All smallholder pig farmers in all villages of two sublocations in each district were determined using key informant interviews with government officials, village elders, and pig farmers. From this list, 288 smallholder pig farms were randomly selected proportional to the number of farms (70–75 %) in each village (Mutua et al. 2011a).

The method of data collection is described in detail by Mutua et al. (2011a). Briefly, farms in the peri-urban district were visited during three study periods: June/July 2007, December 2007/May 2008 and October 2008. Data collection that started in December 2007 was continued in May 2008, because of post-election violence in the area. Farms in the rural district were visited in June/July 2006, October/November 2006, and February/March 2007. All pigs on 288 farms were weighed except pregnant sows, nursing pigs the farmer planned to sell, and pigs that were too heavy for the scale (>100 kg) or too difficult to restrain. Pigs were weighed one, two or three times depending on whether they were still on the farm on subsequent visits or if they were new pigs at the second or third visit.

Each pig was identified with one uniquely numbered/coloured ear tag. Small pigs (<10 kg) were weighed with a hand-held Junbao® spring scale (Yongkang Junbao Appliance Co., Ltd., Zhejiang, China). Larger pigs (≥10 kg) were weighed with a Chatillon® circular spring scale (Chatillon Force Measurement Products, 8600 Somerset Drive, Largo, FL, USA 33773) suspended from a tree. Both scales were accurate to within 0.1 kg.

Data recorded included the ear tag number and colour, breed, weight (kilogram), age (months) estimated by the farmer within 0.5 months, and date on which the data were collected. Genetic background of the pig was crudely estimated by phenotypic observations by one of two authors as follows; local pigs were short of stature, long nosed and predominantly black; exotic pigs, resembling Large White, were taller and longer than the local pigs, shorter-nosed relative to the size of the head, and predominantly white; crossbred pigs had some features of each local and exotic; were of medium stature, moderate nose length and were typically white with some black spots. Digital photographs were taken of each pig's body and head and when the genetic classification was confusing, two authors discussed the most appropriate category in which to place the pig. Pigs were removed from the study during data screening if the weight or age were missing, the unique ear tag could not be verified, or if the pig was older than 12 months of age. All data were entered into MS Excel (Microsoft Corporation, Microsoft Way, Redmond, Washington) then exported to Statistix™ (Analytical Software, PO Box 12185, Tallahassee, FL, USA) for analyses.

Birth weight for pigs in this study was assumed to be 1 kg for all pigs in order to estimate ADG for pigs having only one weight measure. While we realise that the average birth weight of indigenous and crossbred pigs ranges from 0.89 to 1.33 kg (Ncube et al. 2003), we used 1 kg as a standard weight for all pigs. Individual birth weights likely ranged from 0.5 to 1.8 kg, but estimating birth weight as 1 kg would result in very small changes in ADG over several months of the pig's life. While birth weights of less than 0.7 kg do occur, research has shown that these pigs do not survive past 3 days of life (Dewey et al. 2008).

Average daily gain (kilograms per day) was calculated for pigs weighed once as follows: (weight−1 kg)/(estimated age of the pig in days) ($N$=235 peri-urban and 236 rural). For pigs weighed twice, a paired $t$ test was used to determine whether ADG from birth to second weight differed from ADG from first to second weight. For pigs weighed three times, a paired $t$ test was used to determine whether ADG from birth to third weight differed from ADG from second to third weight. Average daily gain of pigs weighed once did not differ from pigs weighed twice ($p$>0.05), so a single ADG from birth was calculated for each pig. Each pig was included only once in the final model. For pigs weighed multiple times, the weight used for model building was randomly selected from the first, second, or third weight. For the final model the initial, second, and third weights were included for 16, 16, and 0 pigs in the peri-urban district and 80, 80, and 65 pigs in the rural district respectively. The ADG was calculated as (weight−1 kg)/number of days from birth to date weighed.

To control for potential confounding of month and year pigs were grouped according to the month and year in which they were weighed. Two months were treated as one variable when a data collection period extended through an entire month and into the first several days of the next month. Gender was measured as either female or male (boars and castrates). Breed effect was measured as local or non-local. Pigs were grouped according to their age in months to explore putative age effect on ADG. Some ages were combined in order to have a sufficient number of observations in each category, as follows: 1 to 2, 7 to 9, and 10 to 12 months.

The population proportion of local and crossbred pigs was determined.

### Statistical analysis model building

Using multiple linear regression ADG was regressed on age of pig (1 to 2, 3, 4, 5, 6, 7 to 9, and 10 to 12 months), district (peri-urban or rural), gender, breed, year, and month of the year. Initially, univariable analyses were conducted and variables were retained for further analysis if $p$ values $<0.20$. Multivariable analyses were conducted using a backward elimination selection process where variables were removed from the model if $p$ values were $>0.05$. Associations, where $p<0.05$, were retained in the final model. Variables whose removal resulted in a >20 % change in coefficients were considered to have a confounding effect and were included in the final model. Age in months was forced into the model as it was the variable of interest. Assumptions for the models were assessed by evaluating standardised residuals, leverage, and influence. Residuals were plotted against the predicted ADG.

## Results

### Peri-urban district

Of 279 pigs weighed, 7 were removed from the model since they were more than 12 months old. Five pigs were omitted as outliers after the Cooks Distance test because the weight did not seem to be feasible given the age as follows: 2 months, 24 kg; 3 months, 34 kg; and 3 pigs at 2 months, 70 kg, and were assumed to be falsely entered data. The final model included 267 pigs; 32 pigs weighed twice and 235 pigs weighed once.

Average daily gain by age category is presented in Table 1. Breed, month and year in which pigs were weighed and gender were not associated with ADG ($p>0.05$). Mean ADG of 3-month-old pigs (0.14±0.046 kg/day) was lower by 0.03±0.013 kg/day than that of 1-to 2-month-old pigs (0.17±0.069 kg/day) ($p<0.05$). Age of pigs accounts for 0.22 % of the variation in ADG (adjusted $R$ squared=0.0022)

### Rural district

Of 422 pigs weighed, 20 were removed because they were more than 12 months old, weight was missing or the pig's identity was unclear. Five pigs were omitted as outliers after the Cooks Distance test because the weight did not seem to be feasible given the age as follows: 1 month, 15 kg; 3 months, 35 kg; 3 months, 30 kg; 2 months, 40 kg; 7 months, 5 kg, and were assumed to be falsely entered data. The final model included 397 individual pigs; 32 pigs weighed three times, 129 pigs weighed twice and the 236 pigs weighed once. Average daily gain by age category is presented in Table 1. Breed, month, and year in which pigs were weighed and gender were not associated with ADG ($p>0.05$). Mean ADG of 3-month-old pigs (0.10±0.046 kg/day) was lower by 0.02±0.009 kg/day than that of 1-to 2-month-old pigs (0.12±0.058 kg/day) ($p<0.05$). Age of pigs accounts for 2.7 % of the variation in ADG (adjusted $R$ squared=0.0271).

**Table 1** Average daily gain (kilogram per day) of pigs by month of age on smallholder farms in two districts of Western Kenya, 2006–2008

| Months of age | N | Mean | SD | Range | 95 % CI | Median |
|---|---|---|---|---|---|---|
| Peri-urban district | | | | | | |
| 1 to 2 | 31 | 0.17 | 0.069 | 0.05–0.31 | 0.14–0.19 | 0.15 |
| 3 | 49 | 0.14 | 0.046 | 0.05–0.25 | 0.15–0.13 | 0.14 |
| 4 | 30 | 0.16 | 0.052 | 0.07–0.27 | 0.14–0.18 | 0.16 |
| 5 | 33 | 0.15 | 0.062 | 0.05–0.30 | 0.13–0.17 | 0.14 |
| 6 | 35 | 0.16 | 0.052 | 0.06–0.32 | 0.14–0.18 | 0.15 |
| 7 to 9 | 63 | 0.15 | 0.061 | 0.03–0.30 | 0.14–0.17 | 0.14 |
| 10 to 12 | 26 | 0.14 | 0.063 | 0.05–0.27 | 0.12–0.17 | 0.13 |
| Total | 267 | | | | | |
| Rural district | | | | | | |
| 1 to 2 | 60 | 0.12 | 0.058 | 0.02–0.26 | 0.10–0.13 | 0.13 |
| 3 | 50 | 0.10 | 0.046 | 0.03–0.27 | 0.08–0.11 | 0.09 |
| 4 | 40 | 0.12 | 0.049 | 0.03–0.24 | 0.10–0.14 | 0.12 |
| 5 | 40 | 0.12 | 0.049 | 0.05–0.26 | 0.10–0.14 | 0.11 |
| 6 | 53 | 0.12 | 0.042 | 0.03–0.25 | 0.11–0.13 | 0.12 |
| 7 to 9 | 83 | 0.12 | 0.046 | 0.04–0.26 | 0.11–0.13 | 0.12 |
| 10 to 12 | 71 | 0.10 | 0.033 | 0.01–0.22 | 0.09–0.10 | 0.10 |
| Total | 397 | | | | | |

Across districts

Overall mean ADG by age, 25th, 50th, and 75th percentiles are presented in Table 2. In pigs that were weighed twice, ADG from birth to second weight did not differ from ADG from first weight to second weight ($p>0.05$). In pigs weighed three times, ADG from birth to third weight did not differ from ADG from second weight to third weight ($p>0.05$).

Gender, and year and month in which pigs were weighed were not associated with ADG ($p>0.05$). After controlling for age and breed, ADG of pigs in the peri-urban area (0.15 ±0.058 kg/day) was higher by 0.04±0.004 kg/day than that of pigs in the rural area (0.11±0.047 kg/day) ($p<0.05$) (Table 3). Average daily gain of 3-month-old pigs (0.12± 0.005 kg/day) and 10- to 12-month-old pigs (0.11± 0.005 kg/day) was 0.02±0.007 kg/day lower than that of 1-to 2-month-old pigs (0.13±0.007 kg/day) ($p<0.05$). Average daily gain of local breed pigs (0.12±0.054 kg/day) was 0.01±0.006 kg/day lower than that of crossbreed pigs (0.15±0.060 kg/day) ($p<0.05$). Overall ADG of weaned pigs, and all pigs, in the two districts was 0.13± 0.002 kg/day. Age of pigs, breed, and district accounts for 14.9 % of the variation in ADG (adjusted $R$-squared= 0.1491). The models met the assumptions for linear regression.

The majority of pigs in this study (87.2 %) were local breeds, and 12.8 % were crossbreeds.

**Table 3** Factors associated with average daily gain of pigs owned by smallholder farmers in two districts of Western Kenya, 2006–2008

Across districts adjust $R^2$=0.1491

| Variable | Regression coefficient | Standard error | $p$ value |
|---|---|---|---|
| Referent: age 1to 2 months | 0.13 | – | – |
| Age 3 months | −0.02 | 0.007 | 0.006 |
| Age 4 months | −0.001 | 0.008 | 0.75 |
| Age 5 months | −0.01 | 0.008 | 0.43 |
| Age 6 months | −0.001 | 0.008 | 0.84 |
| Age 7 to 9 months | −0.001 | 0.007 | 0.52 |
| Age 10 to 12 months | −0.02 | 0.007 | 0.004 |
| Local breed versus crossbreed | −0.01 | 0.006 | 0.049 |
| Peri-urban versus rural district | 0.04 | 0.004 | <0.001 |

## Discussion

Average daily gain of pigs weighed once did not differ from that of pigs weighed twice. In order to calculate ADG, as long as the age of every pig and the estimated birth weight of pigs in the area are known, weighing pigs once provides sufficient information to calculate ADG. Given the challenges and costs associated with weighing pigs on smallholder farms, often located in remote tropical areas with little to no vehicular access, minimising the number of times pigs are weighed is preferable. If pigs only need to be weighed once, the power of a research study of smallholder pigs will be increased if more farms and pigs can be included for the same amount of money. Also, because pigs are sold based on family need, it is not possible to predict that a pig will still be available to be weighed at a particular age as would occur in a commercial setting.

The ADG of pigs on smallholder farms in Western Kenya is much lower than that of European breeds of pigs raised on commercial farms in developed countries. The ADG of pigs in this study did not change with age as it does in pigs on commercial farms in developed countries (Dewey and Straw 2006). Average daily gain of indigenous pigs and pigs of local breeds, i.e. indigenous- and exotic-breed crosses, raised on smallholder and research farms in Africa and Asia is similarly low (Kumaresan et al. 2007; Darfour-Oduro et al. 2009; Chimonyo et al. 2010; Phengsavanh et al. 2010;Mutua et al. 2012).

The lower ADG of newly weaned 3-month-old pigs may be due to a lack of highly digestible specialised feedstuffs required for pigs of this age (Thomson and Friendship 2012). Moreover, pigs in our study were not provided food or water *ad libitum*. The lower ADG of pigs aged 10–12 months may be the result of inadequate feeding of animals nearing maturity. Low ADG

**Table 2** Average daily gain (kilogram per day) of 664 pigs raised on smallholder farms in peri-urban and rural districts of Western Kenya, 2006–2008

| Age of pig (months) | $N$ | Mean | SD | SE | 25th percentile | Median | 75th percentile |
|---|---|---|---|---|---|---|---|
| 1 to 2 | 91 | 0.13 | 0.066 | 0.007 | 0.08 | 0.13 | 0.18 |
| 3 | 99 | 0.12 | 0.051 | 0.005 | 0.08 | 0.11 | 0.15 |
| 4 | 70 | 0.14 | 0.053 | 0.006 | 0.09 | 0.13 | 0.18 |
| 5 | 73 | 0.13 | 0.057 | 0.007 | 0.09 | 0.13 | 0.16 |
| 6 | 88 | 0.13 | 0.050 | 0.005 | 0.09 | 0.13 | 0.16 |
| 7 to 9 | 146 | 0.13 | 0.056 | 0.005 | 0.09 | 0.12 | 0.16 |
| 10 to 12 | 97 | 0.11 | 0.047 | 0.005 | 0.08 | 0.10 | 0.13 |
| Total | 664 | | | | | | |

of pigs regardless of age may be due to farmers not feeding their pigs enough to meet their energy requirements (FAO 2012; Mutua et al. 2012). Kitchen waste and a variety of other feedstuffs are fed to pigs in Western Kenya, but diets are often inadequate, unbalanced, of poor nutritional value, and contain high amounts of carbohydrates (Kagira et al. 2010; Mutua et al. 2012). In the rural area, 81 % of smallholder pig farmers report high cost and lack of feed as production constraints (Kagira et al. 2010) and 65 % report insufficient feed, especially during the dry season, as a major production challenge (Mutua et al. 2011b). Due to lack of pig feed, 31 % leave pigs to feed outdoors mainly on grass (Mutua et al. 2012). Just 5 % of farmers feed commercial feed to their pigs (Kagira et al. 2010).

Average daily gain of pigs in the peri-urban district was higher than that of pigs in the rural district. Agricultural produce markets are more prevalent in the peri-urban than in the rural district and are closer to smallholder farms, providing scavenging pigs with access to readily available waste products. Peri-urban farmers also have ready access to products such as rumen contents and blood, and food waste from restaurants and schools, all of which can be fed to pigs.

Other contributing factors to low ADG might include high amounts of maintenance energy expended by free-range pigs, exposure to elements due to lack of housing, parasite loads, disease, and low genetic potential. Sixty five percent of pigs in the area are kept tethered and 33 % range freely during the dry season and are tethered only during the rainy season. Just 2 % of pigs are kept in shelters permanently and 61 % are without housing (Kagira et al. 2010). Given the area's climate, and lack of pig housing, pigs may frequently be exposed to inclement weather. Energy would then be used to maintain body temperature; decreasing the amount of energy available for ADG and efficient feed conversion.

In the rural area, 84.2 % of pigs are infected with one or more species of nematodes including *Ascaris suum* and *Trichuris suis* (Kagira et al. 2012). Reduced ADG and feed efficiency have been observed consistently in controlled nematode infection trials (Greve 2012). *A. suum* infection can depress feed efficiency and ADG of pigs by up to 10 % (Lee 2012). Pigs free from *T. suis* grow 35 % faster and are 23 % heavier than infected pigs (Hale and Stewart 1979). Given that 31 % of farmers in the area do not deworm their pigs and 33 % of pigs range freely during the rainy season even dewormed pigs are at risk of re-infection by being tethered in, or scavenging in contaminated areas (Kagira et al. 2010). Average daily gain of crossbreed pigs was higher than that of local breed pigs. Given the high prevalence of local breed pigs' lack of genetic improvement, as well as heavy parasite load, and endemic diseases such as enteritis and pneumonia, are likely contributing to the low ADG in this study.

The ADG of pigs in Western Kenya must be improved using feedstuffs available locally, thereby using resources efficiently while promoting sustainable smallholder pig production, and reducing smallholder farmer poverty (Randolph et al. 2007; Mutua et al. 2012). Higher ADG would enable farmers to sell market-weight pigs sooner, produce more kilograms of pork per year, and increase income for routine household expenses, school fees hospital bills, and food shortages (Dewey et al. 2011). Development of diets based on seasonally available local feedstuffs, particularly those unfit or undesirable for humans, will alleviate human/pig food competition. Research is needed to identify these feedstuffs and their nutrient value and to create least-cost balanced diets using them (Mutua et al. 2012). This study found average daily gain of pigs raised on smallholder farms in Western Kenya is very low, indicating high potential for improvement.

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**Conflict of interest** The authors declare they have no conflict of interest.

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