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Influence of Breed and Feeding on the Zootechnical Performance of piglets (*Sus Domesticus* Erxleben, 1777) and their Commercial Profitability in Kindu and its Surroundings, Maniema Province, DRC

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ABSTRACT

This study, entitled "Influence of Breed and Feeding on the Zoo technical Performance of Piglets (Sus domesticus erxleben, 1777) and Their Commercial Profitability," was conducted in the city of Kindu and its surrounding areas, Maniema Province, DRC. This research aimed to analyze pig farming practices in Kindu, focusing on the effects of feeding practices, piglet breed management, and their commercial profitability. This study aimed to test the hypothesis that piglets, when fed balanced rations adapted to their nutritional needs, achieve significant weight gains and growth. Those types of feed (local, balanced local, and balanced) containing 6.6% CP, 17.01% CP, and 17.09% CP, respectively, were formulated and rationed to the three pig breeds used as study material. The 46-day-old piglets were divided into three sub-groups: local breed piglets, crossbred piglets, and Large White piglets. These three groups of piglets were each rationed with the three types of feed for 9 weeks. After a week of pre-rationing followed by the actual rationing, the results show that the piglets benefit from balanced rations and gave better zoo technical performances in general except at the 2nd and 8th week ($p < 0.05$). The difference between the weight averages was not significant. However, feed consumption was (0.63%) and the average weekly weight gain was (0.222 g/week). In second place, the balanced local diet provided average performance. The piglets performed better on the balanced diet, with ($p < 0.05$) significant differences in live weight gain at weeks 5 and 8 (the difference was not significant in other weeks), feed consumption (0.71%), and average weekly weight gain (0.216 g/week).The study found that the utilization rate of balanced ration distribution was significant ($p < 0.05$) for different breeds of piglets that allowed for normal growth rates and rapid weight gain, followed by the balanced local ration. This study demonstrated the need to distribute feed in farms practicing late weaning at 45 days. Indeed, their judicious use in pig production can represent a significant economic benefit. However, data analysis reveals that, despite this income, financial profitability is negative for all the sires monitored during this period, indicating that the expenses incurred for the maintenance of the sires exceed the income generated. Expenses related to piglet rearing over a nine-week period. This profit is equivalent to approximately $ 21.53 per piglet. In contrast to the negative profitability of the sires, the financial profitability observed for the three piglet breeds is positive, indicating more efficient management of production costs for this category of animals. Finally, this practice supports the prospects for improving zoo technical performance in pig farming in the City of Kindu and its surrounding areas.

1. Introduction

As part of the State's disengagement and the "voluntary" policy, the main medium- and long-term development axes aim at improving household incomes, reducing poverty, improving food security, increasing protein availability and reducing expenditure on imports of basic human consumption products. However, it should be noted that the productivity of the agricultural sectors, particularly livestock, is relatively low and that it appears to be a priority to improve livestock management, to enable livestock farmers and economic operators to become professionals and to contribute through the improvement of their skills and management tools to the implementation of sectoral policy (Georges D. Edoukou, 2003). Sus domesticus is an animal species with many potentialities that make it a key resource for agriculture, particularly in Africa and in certain cities of the Democratic Republic of Congo (DRC). Indeed, the pig is distinguished by a short and very early reproductive cycle, as well as a high prolificacy, ranging from 4 to 12, or even 18 to 20 piglets per birth. In addition, this species is characterized by high feed

conversion and excellent adaptation to various ecosystems. These assets have enabled the pig to meet the growing demand for meat, while helping to alleviate the effects of poverty in these regions (Bondombe and Bolembe, 2018).

Furthermore, feed is a key element in limiting competition between resources intended for human consumption and those allocated to animal feed. The feed efficiency of pigs is therefore becoming a central factor in the management of the pork sector. Today, breeders are paid based on the weight of the carcasses produced, which highlights the importance of optimizing breed growth and feed to improve their commercial profitability (Mopaté and Kossou, 2003).In the Democratic Republic of Congo, and particularly in Kindu and its surrounding areas, the concerns of pork producers and consumers are multiple. The promotion of local pig breeds and the use of good feed represent interesting avenues for strengthening the pork sector and meeting the growing demand for meat. It is in this context that this study is conducted, which seeks to explore these aspects in order to promote sustainable and profitable development of the pork sector in Kindu and its surrounding regions.

2. Study Issues

The world's population is currently experiencing exponential growth, but vital natural resources such as animal and plant genetic resources, agricultural land, and water are gradually diminishing (EU, 2013). This population, which was 7 billion in 2014, will increase to 9 billion by 2050, an increase of nearly 30% (Herrero et al., 2012). At this rate, access to livestock products, already difficult, will only worsen. Adapting to this rate of population growth, combined with the adverse effects of climate change, requires new strategies for the sustainable management of these resources. To achieve this, effective and efficient food production is essential. One of the surest ways to achieve this goal is the integrated management of local animal genetic resources to support livestock production for sustainable development. More than a necessity, current and future food and economic challenges require special attention to be paid to the optimal use of zoogenetic resources. To achieve this, the development of short-cycle animal breeding, particularly pork, would better meet this objective, particularly in the Democratic Republic of Congo, where the prohibitions of the Muslim religion and others refraining from the consumption of this meat have very little influence.

In developing countries, agricultural intensification and rapid urbanization are significantly reducing the land available for grazing ruminants. This pressure on agricultural land has led to a reevaluation of pig farming, particularly that of Sus domesticus, which is the most consumed animal in the world, but which remains often neglected in some regions due to poorly adapted breeding practices (Anonymous, 2016). However, pig production represents a promising sector in these countries due to several advantages: its prolific reproduction, its ability to adapt to different environments, and its rapid reproductive cycle (Anonymous, op. cit.). Pig farming is characterized by an annual growth rate of 4%, ahead of that of cattle (2.6%), sheep (2.13%), and goats (2.26%) (Anoper, 2014). It is also characterized by a low level of inputs and generates constant income for populations in peri-urban and rural areas (Leroy et al., 2012). The pork sector has great socio-economic importance and occupies a large part of the meat supply and household income in urban, peri-urban and rural areas (FAO, 2012; Houndonougbo et al., 2012; Aboki, 2011; Djimènou, 2010; Deka, 2008; Mopaté et al., 2006a

It positively impacts a large portion of the population thanks to its value chain, which involves several types of actors, including producers, live pig dealers, pork processors, consumers, and many other stakeholders who use pork and its derivatives for traditional, cultural, religious, and medicinal purposes (Djimènou, 2019; Nahar et al., 2015; Ndébi et al., 2009; Rai et al., 2009; Kala Ngoma, 2007; Nonfon et al., 1994). Economically, the price of pork varies greatly in the Democratic Republic of Congo depending on the category or age group, weight, breed, sex, and production environment, depending on whether it is an urban, peri-urban, or rural area. Indeed, the market value of a weaned piglet varies between $50 and $100, while that of a fattened pig ranges between $200 and $2,500 on average. Income from pig farming and charcuterie is used to cover household needs, children's schooling, healthcare, and other investments (Djimènou, 2010, Mopaté and Kossou, 2003). In addition, the pig sector also constitutes a source of income for promoters of livestock feed production industries (feed mills), millers (corn mills), veterinary professionals and paraprofessionals, transporters, promoters of catering services, not forgetting those involved in the establishment of livestock and catering infrastructures specializing in the marketing of pig meat (Aboki, 2011; Djimènou, 2010; Ayssiwèdé, 2004).

At the sociocultural level, pork was therefore the basis for the accumulation of wealth and the development of domestic slavery (the exchange of pigs for humans), and in the 19th century, it occupied a prominent place in transactions, marriages, and court cases (Kala Ngoma, 2007). In Benin, as in Cameroon, pork occupies a prominent place in the diet and provides other services in various areas, including marriages, funerals, and traditional ceremonies (Houndonougbo et al., 2012; Djimènou, 2010). However, research that could shed light on the various uses of pigs and pig products in Maniema remains virtually nonexistent. Since the government has been slow to organize the rebuilding of the herd, breeders have initiated it in their own way by using exotic pigs, particularly the Large-White breed, followed by crossbreeding them with local pigs (Sogbossi, 2015). The Large-White breed was adopted for its great power of adaptation and acclimatization to tropical regions and its better growth and reproduction performances (Leroy et al., 2012).

The motivations behind the breeding of purebred Large-White pigs and their crossbreeding with local pigs are to compensate for the losses incurred during the advent of African swine fever by producing pigs larger than those of local pigs. However, the loss of the ability to adapt to difficult farming conditions and the resistance traits to various diseases, recognized as attributes of local pigs, are other consequences. (Deka, 2008). However, the so-called improved foreign breeds have not met expectations. In tropical environments, the breeding of these foreign breeds has failed for several reasons. On the one hand, the animals did not survive and on the other hand, they were not productive in this difficult environment subject to climate change where excessive heat and multiple pathologies are prevalent (Adamou-N'diaye et al., 2000; Tibbo, 2006; Gizaw et al., 2013; Ayizanga, 2016). An average daily gain of 114 g/d was observed in the Large-White pig raised on a station in

Benin despite the dietary and health requirements, compared to 200 to 300 g/week in its cradle (Youssao et al., 2009a). The litter size was less than 10 piglets with a weaning mortality rate estimated at 20% (Youssao et al., 2009b).

Furthermore, the breeding area can also have a significant influence on the zootechnical performance of the local African pig (Agbokounou et al., 2016). Indeed, in Kenya, the average daily gain of 150 g/week obtained in the peri-urban area was better at 110 g/week in rural areas (Carter et al., 2013). In traditional breeding, the weight varies from one country to another and according to age. Thus, according to Abdallah Nguertoum (1997), the weight of the local pig is 31 kg at the age of 8 months in Central Africa. In the Democratic Republic of Congo, the average weight at 12 months varies between 30 and 35 kg (FAO, 2012) while at the same age the average weight of the Nigerian pig is 45 kg with a birth weight of 500 g (Anugwa and Okwori, 2008). These performances observed in local pigs in Nigeria are comparable to those observed in the Muong Lay breed of Vietnam with the same birth weight and an average weight of 44 kg in the sow and 52 kg in the boar (Do Duc, 2013).

The precarious breeding conditions (traditional system) of local pigs in Africa and in the Democratic Republic of Congo in particular (Houndonougbo et al., 2012; Umutoni, 2012; Djimènou, 2010; Halimani et al., 2010; Ndébi et al., 2009; Youssao et al., 2008; Mopaté, 2008), do not allow them to express all their zootechnical potential. However, despite studies aimed at improving their feeding and breeding conditions (d'Orgeval, 1997; Agbokounou, 2001; Codjo, 2003), the performances recorded among local pigs in Benin are not yet satisfactory.

On the other hand, the resistance of the local breed to certain pig pathologies has been proven (Muys et al., 2003). Aside from the effects that could be induced by adequate feeding and health monitoring, the performance of local breeds can also be improved genetically through crossbreeding or selection. Thus, when the technical level and feeding level are appropriate, and good breeding practices are respected, genetic improvement results appear quickly. In the context of animal genetic improvement, breed selection (so-called purebred selection) and crossbreeding, exploiting the complementarity between breeds, as well as hybrid vigor or heterosis, are the methods of choice used by animal scientists (Leroy et al., 2012). Indeed, crossing local pigs with other exotic breeds may seem like a faster way to improve performance, with a minimal increase in inputs. However, the higher performance of crossbreds is accompanied by more onerous nutritional and management requirements (disease control, infrastructure, etc.). However, this improvement would only be real if the value of the products derived from the breeding exceeds the cost of the production factors, a factor that is often overlooked by breeders. However, when feed and other resource availability are scarce and the climate is potentially stressful for the animals, achieving higher individual productivity can be costly compared to the benefits obtained (Wiener and Rouvier, 2009). Disregarding the values of our native pigs and neglecting the multitude of sustainability functions of their performance constitutes an attack on biodiversity (FAO, 2006). To better exploit these local resources, it is necessary to employ well-defined breeding processes. Among the main genetic improvement options that exist (breed replacement, crossbreeding, inbreeding, selection, gene transfer, any combination of options), only intra-breed selection is the most common and appropriate way to create something new compared to what already exists (Wiener and Rouvier, 2009). Animal selection progresses through small, cumulative steps, allowing for the slow and methodical implementation of all the necessary adjustments to feeding and general livestock management (Leroy et al., 2012; Wiener and Rouvier, 2009). Selection is the most reliable option for achieving sustainable improvement. But unfortunately, in Benin, it does not often receive the consideration it deserves, for the sole reason that it rarely produces immediate, spectacular results.

Unlike what can be achieved through crossbreeding and breeding with exotic purebreds (Leroy et al., 2012). However, the ability to adapt to adverse production conditions in tropical environments remains a unique attribute of indigenous breeds (Jarvis et al., 2012). Thus, local pigs constitute a heritage to be preserved, a source of innovation for the livestock sector of tomorrow (Naves et al., 2011; Audiot and Rosset, 2004). Global changes in livestock production (changes in systems, areas, business scale, environmental impacts, consumption patterns) will present new challenges for the livestock sector in the DRC and Africa. At the heart of these challenges are, on the one hand, the improvement of the genetic potential of native species in order to maintain the rate of productivity growth and, on the other hand, the preservation and long-term improvement of native animal breeds (Herrero et al., 2014). In the pig sector, the elements of improvement are: (1) litter size (number of piglets per farrowing), (2) weaning weight, (3) feed efficiency, (4) daily gain and (5) carcass qualities (Leroy et al., 2012). Since livestock farming is a dynamic process, the four aspects of prolificacy, daily gain, carcass qualities and feed efficiency must be continuously improved to reduce production costs and increase profit. To conserve, improve and use the genetic variation of local pigs in the long term in the DRC, it is first necessary to characterize it, that is, to measure its extent, its genetic diversity and its distribution. Diversity can be assessed at the phenotypic level and at the genotypic level. The assessment of phenotypic diversity focuses on morphological descriptors, the characteristics that define the shape and appearance of a set of individuals (FAO, 2007; 2013). In any case, phenotypically different individuals can be genotypically identical and vice versa. This is why molecular genetic characterization is essential to provide solid arguments to explain diversity at the phenotypic level. This will highlight the part of diversity due to genetics and that due to the environment. Thus, the results of genetic characterization constitute the necessary orientation bases for decision-making regarding the implementation of programs for the preservation and improvement of livestock. Thus, understanding the impact of breed and feed on the zootechnical performance of piglets, and their economic repercussions, becomes a priority to assess the competitiveness of pig farms in this specific context. Studies by FAO, Vanessa Board et al., (2013) show that economic profitability and optimization of breeding practices are crucial aspects for the effective management of pig production. In this context, it is essential to better understand how genetic selection and feeding influence piglet growth and their commercial profitability in Maniema Province, in order to promote sustainable and profitable breeding practices.

3. Research Questions

In this study, we address the general question:

"What is the influence of breed and feed on the zootechnical performance of piglets and their commercial profitability in Kindu?" From this general question, three specific questions were formulated:

- What are the morphological characteristics of pig broodstock used in piglet production?
- What is the zootechnical performance of piglets based on breed and feed in pig farming?
- What is the economic impact of breed and feed choices on the commercial profitability of pig farms?

4. Research Hypotheses

The hypothesis is that breed and feed contribute positively to the zoo technical performance of piglets and their commercial profitability. The specific hypotheses are as follows:

- The morphological characteristics of the sires vary from one breed to another;
- The zootechnical performance of the piglets varies depending on the breed and the feed given;
- The economic impact of financial profitability on the sires and piglets is relatively positive.

5. Study Objectives

5.1. General Objective

The main objective of this research is to assess the influence of breed and diet on the zootechnical performance of piglets, which is crucial for maximizing their commercial profitability and optimizing breeding practices.

5.2. Specific Objectives

Given the unique nature of this study, we set specific objectives:

♣ To increase pig herd production using sires characterized by the best morphologies;

♣ To evaluate breed growth dynamics as a function of time and piglet diet to improve the animal's highly attractive zootechnical performance;

♣ The economic impact of sires and piglets is assessed through financial and commercial profitability.

6. Significance of the work

This study has three main implications: scientific, socioeconomic, and environmental. Each has important implications for understanding and optimizing pig farming in the Kindu region.

6.1. Scientific

The results of this research will provide fundamental data for understanding the interactions between genetics, nutrition, and the zootechnical performance of piglets. These data will be particularly useful to researchers and practitioners in the fields of animal husbandry, sustainable agriculture, and livestock management systems. Furthermore, the study will also strengthen the knowledge base on pig farming practices in rural areas of the Democratic Republic of Congo and offer avenues for future research on improving animal productivity, particularly in contexts similar to that of Maniema Province. Finally, they could serve as a model for other regions facing similar challenges.

6.2. Socio-economic

From a socioeconomic perspective, the study aims to propose practical solutions to improve pork production and, consequently, access to quality animal protein for the local population. Promoting pig farming in the region could contribute to reducing malnutrition and strengthening food security, a crucial issue in contexts where animal feed resources are limited. Furthermore, increasing pig productivity could have a direct impact on the incomes of farmers and value chain stakeholders, from producers to traders. The study could therefore promote food self-sufficiency and offer new economic opportunities, particularly through job creation in the pork industry and its related sectors (transportation, marketing, processing).

6.3. Environmental aspects

From an environmental perspective, the study focuses in particular on the recovery of mixed manure from agricultural activities as potential organic manure. In this way, it will contribute to reducing the negative impacts associated with the accumulation of this waste in the environment, as well as contributing to environmental sanitation and pollution reduction, by proposing interesting alternatives for recovering residues that could otherwise have a negative environmental impact.

7. Spatio-temporal delimitation

Data collection was carried out in the city of Kindu and its surrounding areas, located in the Maniema Province of the Democratic Republic of Congo (DRC), over a two-year period, from June 15, 2022, to June 15, 2024. The choice of this geographical area was based on several strategic considerations. As the capital of Maniema Province, Kindu represents a central hub for agricultural and livestock activities, particularly in the pig sector. The region's diverse breeding practices, varied socioeconomic conditions, and climatic characteristics provide a representative and relevant framework for analyzing the impacts of genetics, feeding, and livestock management on piglet performance. The two-year data collection period allows for consideration of seasonal variations that directly influence breeding practices, livestock yields, and market conditions. This timeframe also provides sufficient visibility to observe changes in piglet yields and the impact of different genetic and feeding practices over a complete production cycle. Thus, the spatio-temporal scope of this study allows for the production of results specific to local realities while taking into account the dynamic and seasonal factors that influence the performance of pig farms in the region.

8. Presentation of the City of Kindu

8.1 Geographical Framework

The town of Kindu is bounded:

- ❖ in the North, a vertical straight line going from the Misubu river on the right bank, passing through Keka village downstream of the Congo river, towards the left bank of the Congo river in the North left of the Kindu airport runway up to its intersection with the Kindu – Lokando road near the Lwama cemeteries;
- ❖ to the South, a straight line starting from the source of the Mikonde River to its mouth upstream of the Congo River, going from the right bank to the left bank at the mouth of the Mukolochi River passing by Rail road until at the Kibombo road crossing;
- ❖ to the East, a straight line starting from the source of the Mikonde River to its intersection going to the right of the Misubu River bridge;
- ❖ to the West, by a straight line which starts from the Lokando crossing, only from Lwama passing by the Mikelenge river bridge on the Katako – Kombe road to the Kibombo road.

The town of Kindu is made up of three communes, one of which is on the right bank, that of Alunguli, and two others on the left bank. These are Mikelenge and Kasuku. It extends over an area of 101,259 km² and with an altitude of 487 m, i.e. 25°47' East longitude and 2°47' South latitude. (Morel, 2007).

Municipality of Kasuku

Entirely located on the left bank of the Congo River, Kasuku is an urban commune. It is limited to the north by the Bangengele chiefdom in Kailo territory, to the west and south by the Kapondjo and Mikelenge rivers which separate it from the commune of Mikelenge, to the east by the Congo river formerly (Lualaba) which separates it from the commune of Alunguli. It is the main commune of the town of Kindu, due to its central geographical position and especially the concentration of socio-professional activities and public infrastructures. The governorate offices, the provincial government as well as the City Hall are located in this commune. (Figure 1)

Municipality of Mikelenge

Entirely located on the left bank of the Congo River, Mikelenge is an urban-rural commune. It is limited to the north by the Lwama road; to the east by the Kapondjo, Mikelenge and Lualaba rivers; to the South by the village Libenga; to the west by kilometer point 10, Mikelenge houses the headquarters of the Provincial Assembly of Maniema. (Figure 1)

Municipality of Alunguli

Entirely located on the right bank of the Congo River, Alunguli is an urban-rural commune (figure 1). It opens the city to the mining sites in the east (Kaïlo, Kalima, etc.) and the Kasongo Territory to the south. Its population is made up of more than three quarters by the Lega, the rest being made up of the Genya (falsely called here Lokele), followed by the Songola (N'sanda, 2011).

Table 1: Structure and area of the town of Kindu

Municipalities	*Neighborhoods*	*Blocks*	*Avenues*
Alunguli (25 km²)	Kama II	6	35
	Kabondo	3	6
	Mangobo	9	53
Subtotal	***3***	***8***	***94***
Kasuku (30 km²)	Basoko	7	48
	Kasuku	6	130
	Lwama	7	34
Subtotal	***3***	***20***	***212***
Mikelenge (46,297 km²)	Lukunda	7	20
	Mikelenge	8	27
	Tokolote	8	69
Subtotal	***3***	***23***	***116***
Grand Total	**9**	**61**	**422**

Area = 101,295 km²

Anonymous 2018.

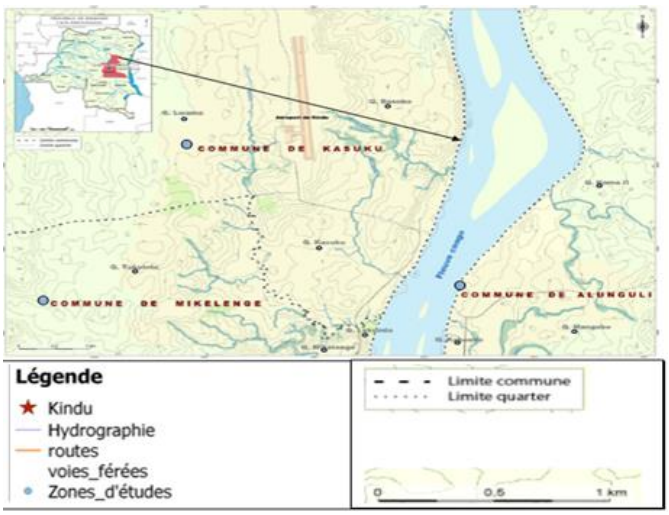


Figure1. Location of study environments source: personal initiative

8.2 Biophysical Framework

a) Soil and relief

The relief is that which characterizes the end of the central Congolese basin, very uneven with the soil which varies between the clay-sandy and sandy-clay type. This region has agricultural soil which allows the cultivation of all kinds of crops, both food and cash (Yuma, 2016).

b) Climate and vegetation

According to the meteorological service and according to the KÖPPEN classification, the city of Kindu is characterized by a hot and humid climate which evolves from the equatorial type to the North. The average temperature is around 25 to 27°C and precipitation amounts to 1650 mm.

The climate is characterized by:

- A rainy season which occurs twice a year: from August to December and from January to mid-May.
- A dry season which does not exceed 4 months, which goes from mid-May to mid-August, accompanied by fog during the morning and disparate fine rains.
- Season A normally begins in mid-September until January and season B begins in February until May. Thus, the climatic data from our work are presented in the table below:

The primary vegetation of this city having been destroyed for a long time, it contained valuable species in particular: Chlorophoraexcelsa, Entadrophragmaborea, and others which have now given way to grasses and legumes, shrubs and shrubs. Among them, we cite Musangacecropioides, Eupatoriumodoratum, Hyparrheniasp, Puerariajavanica , Elaeis sp, etc. (Yuma, 2016).

c) Hydrography

It is essentially composed of the Congo River and its tributaries located on either side of the said river. On the right bank, there are the following tributaries: Kindu, Kange, Mikonde, Luambondo, Muchondo, Mangobo, Kamikunga and Musubu. On the left bank we have: Mikelenge, Luandoko, Makopo, Canals,. (Yuma, Op cit).

8.3 Population

The estimated size of the population is 453,9411 inhabitants, according to demographic forecasts established

with reference to data provided by the three municipalities of the city and on the basis of an average rate of change in thepopulation observed during the period of 2018.

As for religion, 4 large groups dominate the city: Catholics, Muslims, Protestants and those from revival churches. Believers in revival churches are growing sharply in the city. (City Hall, 2019)

8.4 Socio-Economic Situation

According to (Yuma, 2016), the town of Kindu is essentially agricultural. Some Kindu residents farm on the outskirts of the town to meet their needs. The food crops generally grown are: Rice, Corn, Cassava, Banana, etc. It is also grown in a small proportion of perennial crops (robusta coffee and oil palm).

Regarding livestock, the population of Kindu traditionally practices the breeding of small livestock (pig, goat, rabbit, sheep, guinea pig) and the breeding of poultry (chicken, duck, pigeon, didon, guinea fowl, …). Fish farming is also practiced there.

Generally, the city's state-owned enterprises are old; this is particularly the case of: REGIDESO (Water Distribution Authority); SNEL (National Electricity Company); the SNCC (National Railway Company of Congo); O.R (Road Office) etc. (Onadambo, 2015).

9. Materials and methodological approach.

Study Materials

The study required the use of several types of materials, which can be classified into three distinct categories: biotic, abiotic, and technical materials.

Biotic Materials

This includes the animals observed and used for the study. These animals are essential for understanding the impact of different feed rations and husbandry systems on pig production. The types of pigs used are as follows:

• Local breeding stock (four sows and one boar): These are pigs from the local breed, known for their good adaptation to the region's environmental conditions.

• Crossbred breeding stock (four sows and one boar): This group consists of pigs crossed between the local breed and other external breeds, with the aim of observing the effect of crossbreeding on animal productivity.

• Large White breed sires (four sows and one boar): This breed is renowned for its good performance in terms of growth, yield, and cosmopolitan character; it was chosen to compare its productivity with that of two other groups. These animals were purchased from local producers in Kindu, which helped ensure genetic diversity and representativeness of local conditions.

Abiotic Material

Abiotic material consists of non-living elements, primarily the resources used to feed animals and ensure their well-being.

In this study, three types of feed rations were used:

• Local ration: This ration is composed of local ingredients in a non-optimized manner, without taking into account the animals' specific nutritional needs.

• Balanced local ration: Unlike the first, this ration is formulated to better meet the nutritional needs of pigs, while using local ingredients.

• Balanced ration: This is a precisely formulated ration, including a balanced combination of proteins, carbohydrates, and other nutrients necessary for optimal piglet growth. These rations were carefully prepared to assess their effect on animal health and growth throughout the study.

Technical Equipment

The technical equipment includes the tools and equipment needed for the daily management of the study, data collection, and pig observation. The main equipment used is as follows:

• Motorcycle: Allows for easy movement in the field and the transport of materials and feed rations required for the study.

• Notebook and pen: Used to take detailed notes on the animals' progress and observed behaviors, and to record data related to each field observation.

• GPS: This device was used to precisely locate the experimental sites and ensure the accuracy of the geographical surveys of the different breeding areas.

• Modem: Provides an internet connection while traveling in the field, facilitating communication with external collaborators and access to online resources.

• Computer and peripherals: Used for processing the collected data, statistical analysis, and writing the final reports.

• Digital camera: This equipment allowed for visual documentation of the various phases of the study, including animal development, treatment application, and field observations.

• Scale: Essential equipment for measuring pig weights at different stages of growth to monitor the impact of feed rations on their development.

• Sprayer: Used for applying health treatments or other interventions related to animal health management.

9.1 Methods

The methodological approach adopted in this research is based on a mixed approach combining field observation, rigorous on-station experimentation, and in-depth economic analyses. It aims to comparatively evaluate the zootechnical and economic performances of local, crossbred, and improved breed pigs, fed three distinct diets. This protocol, which draws on a solid experimental foundation, allows for a cross-analysis of the technical and economic variables that determine the direction of pig farming systems in tropical environments. This methodological approach is inspired by the work of Cadéro (2017) and Soleimani (2022), who emphasize the importance of a combined analysis to maximize the efficiency of livestock production systems in specific contexts.

9.1.1. General methodological approach

The methodology adopted is based on a systemic approach, integrating phases of participatory observation and controlled experimentation. This approach draws on the methodological principles put forward by Gouttenoire (2010), who emphasizes the need to cross-reference data collected in the field with data from rigorous experimentation to ensure better adaptability of the systems studied to local realities. Such a method allows for a comprehensive understanding of livestock systems, taking into account socioeconomic and technical factors.

9.1.2. Participatory Observation

An initial phase of direct observation was conducted in several livestock units in Kindu and its surrounding areas. The observation allowed for the collection of data on feeding, health management, and housing practices, while assessing farmers' perceptions of pig breeds.

This type of approach is widely recommended by Moustier et al. (2010), who emphasize the importance of

immersion in the local context to ensure the relevance of applied research. The observations served to adjust the experimental protocol and ensure that local practices were taken into account in the development of the experimental design.

Figure 2. Data collection at the Pig Farm of the Faculty of Agricultural Sciences / Department of Animal Science at the University of Kindu.

9.1.3. Literature Review

A comprehensive literature review was conducted using academic and technical sources available online, including theses, scientific articles, and technical reports. The work of Cadéro (2017), which studies the performance of pig breeds in tropical climates, served as a basis for selecting the main zootechnical and economic indicators to be analyzed. This literature review places the study within a solid theoretical framework and ensures that the measured parameters are consistent with those used in the existing scientific literature on pig farming in tropical environments.

9.1.4. Experimental Design

The experiment was conducted in the piggery school of the Faculty of Agricultural Sciences at the University of Kindu. A total of 45 piglets, divided into three breeds (local, crossbred, and improved), were fed three diets: local ration, balanced local ration, and balanced ration. This type of experimental design has been validated by Soleimani (2022) in his work on pig farming, highlighting the effectiveness of factorial trials in identifying interactions between the different factors studied. This protocol made it possible to compare the effects of breed and diet on the productivity and profitability of pig farming in tropical climates.

9.1.5. Data Collection Techniques

Data were collected systematically using specific monitoring sheets to record individual animal performance, such as weekly weight gains. Information on production costs, including feed, veterinary care, and labor, was also collected. According to FAO (2012), this quantitative approach is essential for rigorously documenting technical and economic aspects in comparative pig farming studies. These data were used to calculate profitability indicators, such as gross margin and return on investment.

9.1.6. Sampling

The experimental sample of 45 piglets was divided into three equal groups, each subdivided into three subgroups according to the type of feed ration. This approach, inspired by random and purposive sampling methods (as recommended by Védie et al., 2015), limits bias while maintaining scientific rigor in the analysis of results. The sample size was determined based on logistical constraints and the need for precise results.

9.1.7. Measured Zoo technical and Economic Parameters

The zootechnical parameters measured or observed include birth weight, weaning weight, average daily gain, feed conversion ratio, meat yield (carcass yield), and mortality rate. These parameters are commonly used in studies on the zootechnical performance of pig breeds, as highlighted in the work of Védie et al. (2015). The economic aspects studied include total production cost per animal, gross margin, return on investment, and net profit per animal. These indicators are crucial for assessing the profitability of pig farming and have been used in similar studies, such as those of Cadéro (2017).

9.1.8. Variables studied

The independent variables are pig breeds (local, crossbred, and improved) and feed types (local ration, balanced local ration, balanced ration).

The dependent variables include zootechnical parameters (growth weight, feed consumption) and economic variables (financial profitability).

This cross-referencing of variables makes it possible to identify optimal configurations for increasing pig production, as shown by similar studies on pig farming in tropical climates (Soleimani, 2022). Profit ($) = production value ($) - total production cost;

1. Production value = Number of piglets x Selling or unit price; Production cost: (Breedstock feed ($/year), Ration transportation cost ($/year), Veterinary fees ($/year), labor ($/year), purchase of breeders, depreciation. (Muanasaka et al 2020)

$$\text{2. Financial profitability (\$)} = \frac{\text{Profit}}{\text{Total or overall cost}} \times 100$$

$$\text{3. Commercial profitability (\%)} = \frac{\text{Profit}}{\text{Turnover}} \times 100$$

9.1.9. Data Processing and Statistical Analysis

The collected data were processed using Microsoft Excel software, applying descriptive statistical methods to summarize the results obtained with their mean, variance, standard deviation, and coefficient of variation.

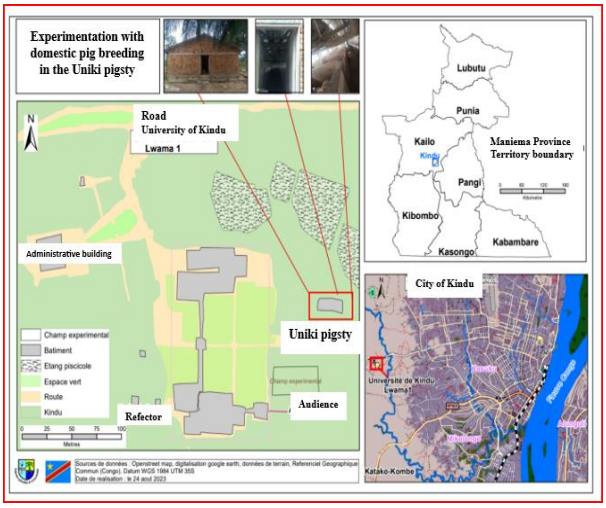
For advanced analyses, factor analysis and cluster analysis techniques were used to better understand the relationships between different parameters and identify key factors influencing pig performance.

These statistical techniques are widely used in pig breeding research, as demonstrated by the use of STATGRAPHICS Plus software for multivariate and spatial analyses (Védie et al., 2015; Soleimani, op. cit.).

Figure 3. below illustrates the location of study environments within the University of Kindu and its territories.

Ultimately, this chapter has provided a detailed description of the geographical, socioeconomic, and environmental framework of the study, as well as the material and methodological resources mobilized for its implementation. The choice of the city of Kindu as the study setting is based on its representativeness of pig farming conditions in a humid equatorial zone, where technical, dietary, and economic constraints still limit farm productivity.

This contextualization is essential to ensure the relevance and applicability of the results obtained (Tchoumboué et al., 2001; FAO, 2012). The methodological approach adopted combines participatory observation, rigorous experimentation, and statistical analysis, in accordance with the recommendations of applied research in tropical animal production (Gouttenoire, 2010; Soleimani, 2022). The factorial experimental design implemented made it possible to compare, under controlled conditions, the effect of different diets on the performance of pigs of different breeds. The systematic collection of zootechnical and economic data, followed by analytical processing using specialized software, ensures the reliability and robustness of the expected results (Védie et al., 2015; Charlier et al., 2018). This methodology thus provides a solid scientific basis for meeting the study's objectives, namely the identification of the most effective breed-feed combinations, both technically and economically, in the specific context of Kindu. The following chapters will focus on the presentation, analysis, and interpretation of the results obtained from this rigorous approach.



Data source: RGC, Terrain Data, Opeestreat map, Datum WGS UTM 35S.

Date of completion: September 4, 2023.

Figure 3. Map illustrating the sampling sites of the Pig Farm

10. Results

This chapter presents the results of the experiment conducted in the University of Kindu's piggery school, as part of a comparative analysis of the zootechnical and economic performance of local, crossbred, and improved pig breeds fed three types of compound feed.

The objective is to highlight significant differences between breed-ration combinations, both in terms of growth parameters and economic profitability. The analyzed data allow for the assessment of sire morphology, piglet growth rate, and the direct impacts of nutrition on zootechnical performance. At the same time, particular attention is paid to the economic components of the farm, including production costs, sire and piglet profitability, and pork marketing dynamics in Kindu.

All collected data was statistically processed and presented in graphs and tables to facilitate reading, summarize observed trends, and support the interpretation of results.

This presentation is based on a rigorous approach, in line with the methodological approaches described in recent scientific literature (Dossa et al., 2011; Siala et al., 2018; Houessou et al., 2020), while integrating the local realities of pig farming in tropical environments. (Mukandama, Muanasaka and Myonge (2020)

10.1. Zootechnical Parameters Observed

In any livestock enterprise, analyzing zootechnical performance is a fundamental step in assessing production potential and identifying factors influencing profitability.

This study paid particular attention to the morphometric parameters of sires, piglet growth performance, and the influence of feed ration types. Indeed, breed and diet are recognized as major determinants of zootechnical performance in pig farming. Understanding their interaction not only allows for a diagnosis of current practices, but also guides choices in genetic selection and feed formulation with the aim of improving productivity.

This section presents the results obtained on the morphometric characteristics of sows and boars according to the breeds studied (local, crossbred, and improved), as well as on the weight gain of piglets. It also analyzes the effects of different feed rations on weekly weight gains of piglets, while highlighting the practical implications for efficient technical management of pig farms in the context studied.

10.1.1. Morphometric Characteristics of the Sire Sows

The table below presents the average morphological characteristics.

Table 2. Characteristics of the average morphotypes of the sows (level of significance)

Sow breeds	Snout length (cm)		Body length (cm)		Chest perimeter (cm)		Height at withers (cm)		Height at sacrum (cm)		Body weight (Kg)		Circumference of snout (cm)		number of pacifiers
	4 months	8 months	4 months	8 months	4 months	8 months	4 months	8 months	4 months	8 months	4 months	8 months	4 months	8 months	
	4 mois	8 mois	4 mois	8 mois	4 mois	8 mois	4 mois	8 mois	4 mois	8 mois	4 mois	8 mois	4 mois	8 mois	
Local	19,50 ±0,62^{a}	32,80 ±2,03^{a}	68,89 ± 1,82^{a}	83,66 ± 1,67^{b}	66,68 ±3,65^{b}	80,29 ± 1,75^{b}	42,73 ± 1,80^{b}	63,71 ± 3,11^{a}	47,45 ± 1,05^{ab}	58,67 ± 3,17^{b}	32,34 ± 1,66^{b}	49,28 ± 3,51^{b}	25,54 ±0,59^{a}	41,51 ± 2,76^{a}	14
Mixed race	18,60 ± 1,78^{ab}	34,05 ± 2,63^{a}	71,89 ± 1,70^{a}	89,00 ± 2,55^{c}	66,22 ±3,23^{b}	88,69 ± 0,65^{c}	43,69 ± 2,74^{b}	76,65 ± 2,27^{b}	50,38 ±1,43^{b}	65,02 ± 3,75^{c}	34,71 ± 2,33^{b}	55,93 ± 4,22^{c}	27,52 ±3,90^{a}	48,83 ± 3,16^{b}	16
Large white	16,37 ± 1,19^{b}	37,84 ±3,10^{a}	70,31 ±0,84^{a}	98,89 ± 0,77^{a}	83,80 ±1,24^{a}	93,76 ± 3,24^{a}	52,48 ±2,03^{a}	79,60 ± 4,45^{a}	53,27 ±2,50^{a}	3,50 ±2,57^{a}	41,96 ±1,58^{a}	73,75 ± 1,23^{a}	28,96 ±1,12^{a}	54,38 ± 3,27^{a}	18
Significance (p-value)	0,0495 *	0,0611 ns	0,0694 ns	0,000292 ***	0,000445 ***	0,000347 ***	0,00028 ***	0,00022 ***	0,00409 **	0,000355 ***	0,000134 ***	0,000602 ***	0,189 ns	0,000914 ***	

Numbers with the same letter on the same line do not show any significant differences. *: Significant differences; **: Highly significant differences; ***: Very highly significant at the 0.1% level; ns: Not significant.

Table 2 above shows that the average morphometric characteristics of sows from breeds without studies vary significantly, revealing differences. Local breed sows have the smallest dimensions, with a body length ranging from 68.89 ± 1.82 cm to 83.66 ± 1.67 cm, and a growth weight ranging from 32.34 ± 1.66 kg to 49.85 ± 3.51 kg. They also have an average number of teats of 14, an important factor that can influence their suckling capacity as well as piglet survival. Crossbred sows have intermediate morphometric performances. Their body length varies from 71.89 ± 1.70 cm to 89.00 ± 2.55 cm, with growth weights ranging from 34.71 ± 2.33 kg to 55.71 ± 4.22 kg. The average number of teats is higher (16), reflecting a potentially better maternal capacity. Finally, improved breed sows (Large White) are distinguished by their superior characteristics. Their body length varies from 70.31 ± 0.84 cm to 98.89 ± 0.77 cm, with greater growth weights, from 41.96 ± 1.58 kg to 73.75 ± 1.23 kg. They also have the highest average number of teats (18),

which confirms their strong genetic potential for reproduction and breastfeeding.

Table 3 above shows that the same trends in morphological characteristics observed in sows of the aforementioned breeds were also confirmed in boars. Indeed, the local breed boar at the end of the experiment weighed relatively little (20.5 kg) compared to the crossbred breed boar (24.6 kg) and even less than the improved Large White breed boar (31.7 kg). The latter therefore confirms the superior performance of the genetic piglet in terms of the phenotypic traits under study.

Table 3. Average characteristics of boar morphotypes

Boar breeds 6-10 moths	Snout length (cm)	Body length (cm)	Chest perimeter (cm)	Height at withers (cm)	Height at sacrum (cm)	Body weight (Kg)	Circumference of snout (cm)	number of testicles
Local	18,5 (21,33-39,83)	38,1 (73,65-111,75)	38 (69,50-107,5)	24,3 (47,62-71,92)	25,2 (49,50-74,7)	20,5 (35,53-56,03)	14,4 (26,97-41,37)	2
Mixed race	33,3 (19,64-32,94)	41,4 (85,43-126,83)	39 (84,87-123,87)	29,8 (59,25-89,05)	29,5 (61,15-90,65)	24,6 (47,65-72,25)	19,5 (29,33-48,83)	2
Large white	11,8 (17,35-29,15)	44,9 (87,66-132,56)	43,5 (95,52-139,02)	33,7 (65,57-99,27)	33,9 (67,25-101,15)	31,7 (55,84-87,54)	24,7 (32,25-56,95)	2

10.1.2. Weight gain increase relative to breed and diet over 9 weeks.

The weekly weight gain results for piglets from the breeds studied are shown in the following table:

Table 4: Weight gain of piglets by breed examined

Races	Weeks								
	1	2	3	4	5	6	7	8	9
Local	0.62±0.22^{a}	0.60±0.29^{a}	0.66±0.24^{a}	1.01±0.35^{a}	1.10±0.42^{b}	0.99±0.51^{a}	1.34±0.43^{a}	1.61±0.51^{b}	1.68±0.65^{a}
Mixed race	0.73±0.47^{a}	0.88±0.49^{a}	0.98±0.43^{a}	1.24±0.52^{a}	1.39±0.52^{ab}	1.37±0.70^{a}	1.63±0.67^{a}	2.13±0.43^{ab}	2.15±0.57^{a}
Large white	1.11±0.47^{a}	1.36±0.43^{a}	1.31±0.45^{a}	1.59±0.64^{a}	1.78±0.65^{a}	1.73±0.81^{a}	1.83±0.66^{a}	2.45±0.51^{a}	2.31±0.89^{a}
Significance (p-value)	0.4190 ns	0.3830 ns	0.0574 ns	0.2729 ns	0.0028 **	0.0784 ns	0.9823 ns	0.0285 *	0.4640 ns

Numbers with the same letter on the same line do not show any significant difference. p: probability; **: Highly significant differences; *: Significant differences. ns: Not significant These results confirm the impact of breed on piglet growth performance, consistent with the initial hypotheses. The weekly weight gain results for each of these breeds generally varied numerically from start to finish. However, these increases were quite significant for the improved breed, followed by the crossbred breed, and finally the local breed, as revealed by analyses of variance, especially at weeks 5 and 8, respectively (p = 0.028**) and (p = 0.0285*).

Table 5. Weight gain of piglets per ration distributed

Rations	Weeks								
	1	2	3	4	5	6	7	8	9
Local ration	0.58±0.21^{b}	0.57±0.28^{a}	0.57±0.43^{b}	0.79±0.14^{b}	0.82±0.20^{b}	0.69±0.17^{b}	1.55±0.23^{b}	1.47±0.43^{a}	1.27±0.41^{b}
Balanced local ration	0.92±0.45^{ab}	1.03±0.47^{a}	0.95±0.23^{ab}	1.13±0.26^{ab}	2.03±0.32^{ab}	1.20±0.33^{ab}	0.97±0.26^{ab}	2.17±0.26^{a}	2.39±0.29^{ab}
Balanced ration	0.96±0.55^{a}	1.24±0.52^{a}	1.43±0.43^{a}	1.92±0.41^{a}	2.03±0.44^{a}	2.21±0.55^{a}	2.27±0.43^{a}	2.56±0.42^{a}	2.49±0.74^{a}
Significance (p-value)	0.0482 *	0.4900 ns	0.0119 *	0.0350 *	0.0136 *	0.0308 *	0.0013 **	0.3680 ns	0.0170 *

Numbers with the same letter on the same line show no significant difference. p: Probability **: Highly significant difference; *: Significant difference; ns: Non-significant difference.

The effect of feed ration was also examined in Table 5, which shows statistically significant differences at weeks 1 (p=0.0482*), 3(p=0.0119*), 4(p=0.0350*), 5(p= 0.0136*), 6(p=0.0308*), 7(p=0.0013**), and 9(p = 0.0170*). Only weeks 2 and 8 showed no significant difference. These results reveal that feed quality, particularly nutritional balance, directly influences piglet weight gain over the weeks.

10.1.3. Piglet Weight Gain Dynamics by Breed over 9 Weeks

The weekly evolution of piglet weight gain by breed was plotted (Figures 4 to 6).

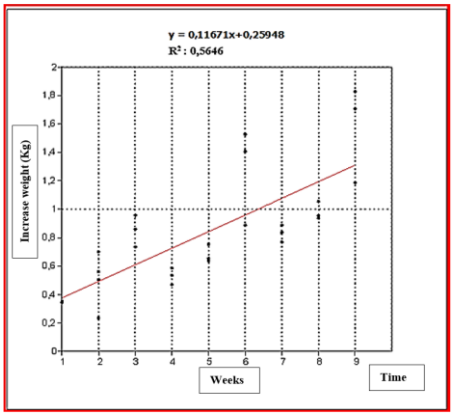


Figure 4: Average Weekly Growth and Weight Gain of the Local Breed

Figure 4, for the local breed, shows an average weekly growth of 0.11671 g and a live weight gain of 0.25948 g. These results reflect moderate growth, typical of local breeds with little genetic selection.

The weekly evolution of weight gain of piglets according to breed was represented by the graphs below:

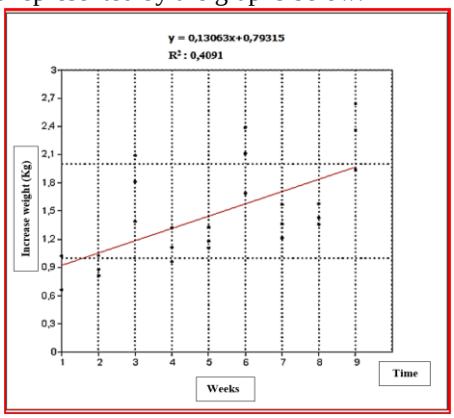


Figure 5: Weekly weight gain and weight gain of the crossbred breed

This figure, for its part, concerns the crossbred breed and reveals a greater weekly gain of 0.13063 g, as well as a live weight gain of 0.79315 g. This performance highlights a zootechnical improvement, attributed to the heterotic effect resulting from the crossbreeding.

The weekly evolution of weight gain of piglets according to breed was represented by the following graphs:

Figure 6, for the improved breed (Large White), highlights superior results with a weekly gain of 0.21691 g and a live weight gain of 0.87666 g. These performances reflect favorable genetic selection, conducive to rapid growth,

a desirable characteristic in commercial herds. The figures above illustrate the weekly growth trends of piglets for the different breeds (Locale, Crossbred, and Large White), compared to the corresponding time periods.

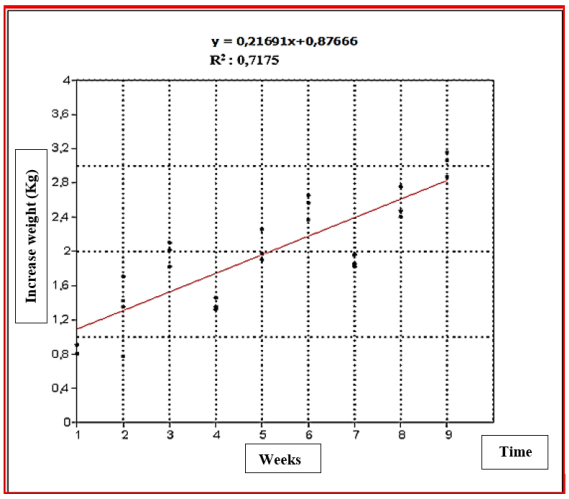


Figure 6: Weekly Gain and Live Weight Trends of Improved Piglets (Large White)

10.1.4. Piglet Weight Gain Dynamics According to Dietary Rations Over 9 Weeks

Figures 7 to 9 present the dynamics of piglet weight gain according to the diets used.

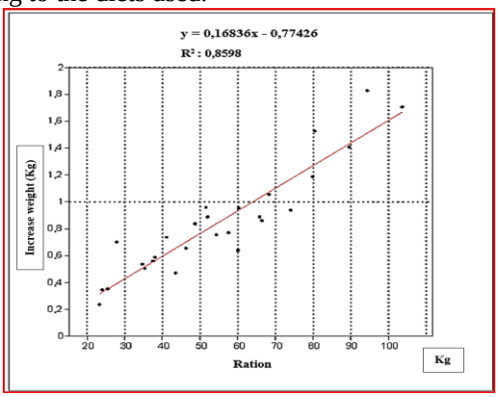


Figure 7: Average weekly gain of piglets fed the local diet.

The figure above illustrates the results for piglets fed the local diet, which recorded an average gain of 0.16836 g per week, or 0.77426 g in live weight. These results highlight moderate growth, typical of local diets.

Figures 8 present the dynamics of piglet weight gain according to the rations used.

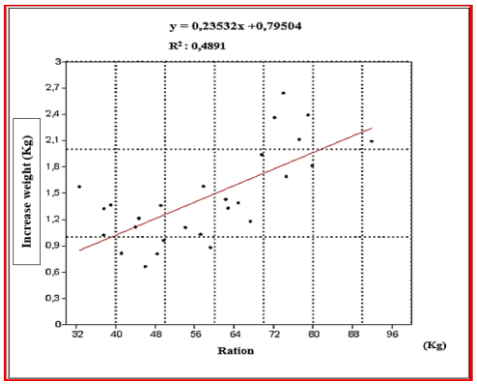


Figure 8: Average Gain of Piglets Fed the Unbalanced Local Diet

This figure above shows that the unbalanced local diet results in a slightly higher average gain of 0.23532 g per week, or 0.79504 g of live weight. However, although performance is better than that observed with the balanced local diet, it remains lower than that of piglets fed a fully balanced diet, highlighting the importance of optimized feeding for better growth.

Figure 9 shows the dynamics of piglet weight gain according to the rations used.

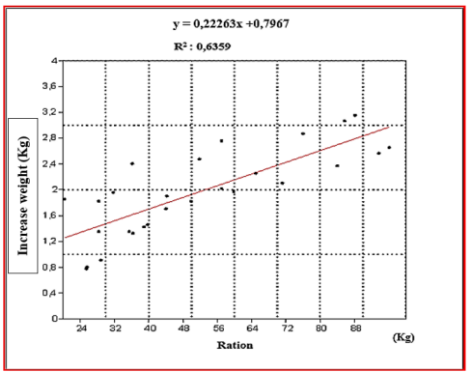


Figure 9: Growth Weight Gain with the Balanced Diet

This figure illustrates a growth weight gain of 0.22637 grams per week and 0.07967 grams of live weight, allowing us to assess the impact of the balanced diet on piglet growth. These results suggest an increase in weight, confirming the effectiveness of the balanced diet in promoting better weight gain.

10.2. Impact of Economic

Valorization on the Pork Industry Economic assessment of the pork industry is essential not only to understand the profitability of breeding practices, but also to guide the choices of stakeholders in this sector towards more efficient and profitable strategies. Optimizing production costs, as well as analyzing the profitability of different animal categories, is a key factor in ensuring the sustainability and competitiveness of pig farms. This section highlights the economic impact of the valorization of brood stock and piglets in pork production. It also includes an analysis of marketing channels, which is crucial for understanding the dynamics of pork supply and demand in urban and rural areas.

10.2.1. Expenditure Costs of Brood stock

The relative results of various costs from our observations are shown in the table below:

Table 6. Expenditure costs of broodstock farmed for 12 months.

Breed of sires (sows and boars)	Number of parents	Cost of purchasing broodstock ($)	Feeding of breeders ($/year)	Transportation costs ration ($/year)	Veterinary fees ($/year)	Labor ($/year)	Labor ($/year)	Selling price ($)	Profit ($)	Profitability ($)
Local	5	250	594,75	62.5	100	225	1232,25	750	-482,25	-39,13
Mixed race	5	350	594,75	62.5	100	225	1332,25	900	-432,25	-32,44
Large white	5	500	594,75	62.5	100	225	1482,25	1000	-482,25	-32,53

These results show that total expenses for sire maintenance are $4,045.75 over the 12-month period. On average, each sire pig costs $269.71 until first farrowing and generates a revenue of $2,650, or a net profit of $176.6 per animal. However, data analysis reveals that, despite this revenue, profitability is negative for all sires monitored

during this period, indicating that expenses incurred for sire maintenance exceed the revenue generated. This negative profitability could be attributed to several factors, including the high cost of veterinary care and sire feed. This suggests that strategies must be implemented to reduce costs or improve the economic returns of sires. In other words, the economic characteristics of sires in this specific setting do not allow for economically viable operations in the short term.

Below we illustrate the cost structure of the expenses incurred for each breed of sires:

Table 7. Cost structure section for local breed sires.

Breed of sires (sows and boars)	Cost of purchasing broodstock ($)	Feeding of breeders ($/year)	Transportation costs ration ($/year)	Veterinary fees ($/year)	Labor ($/year)	Labor ($/year)
Locale (5)	250	594,74,	62,5	100	225	1232,25
%	*20,29*	*48,26*	*5,07*	*8,11*	*18,25*	*100*

Regarding the local breed, we note that the most important item is feed (48.26%), followed by the cost of purchasing the breeders (20.29%), then labor and veterinary fees with an incurred expense of (18.25% and 8.11%) and the cost of transporting the ration (5.07%).

Table 8. Cost structure item for crossbred breed breeders.

Breed of sires (sows and boars)	Cost of purchasing broodstock ($)	Feeding of breeders ($/year)	Transportation costs ration ($/year)	Veterinary fees ($/year)	Labor ($/year)	Labor ($/year)
Mixed race (5)	350	594,75	62,5	100	225	1332,25
%	*26,26*	*44,64*	*4,69*	*7,50*	*16,88*	*100*

For the mixed breed, we note that the feed section had (44.64%), followed by the cost of purchasing the sires (26.26%), regarding labor and veterinary costs, the expense had (16.88% and 7.50%) and finally the ration transportation costs cost (4.69%).

Table 9. Cost structure section for sires of the Large White breed.

Breed of sires (sows and boars)	Cost of purchasing broodstock ($)	Feeding of breeders ($/year)	Transportation costs ration ($/year)	Veterinary fees ($/year)	Labor ($/year)	Labor ($/year)
Large White (5)	500	594,75	62,5	100	225	1482,25
%	*33,73*	*40,12*	*4,21*	*6,74*	*15,17*	*100*

Regarding the Large White breed, we found that feed had an expense of (40.12%), followed by the cost of purchasing the breeders (33.73%), labor and veterinary costs had an expense of (15.17% and 6.74%) and finally the cost related to the transport of ration was (4.21%).

10.2.2. Piglet Expenditure Costs Below, we illustrate the expenses related to piglet rearing over a 9-week period.

Table 10. Expenditure costs for piglets raised over a 9-week period.

Piglet breed	Number of piglets	Feeding of breeders ($/year)	Transportation costs ration ($/year)	Veterinary fees ($/year)	Labor ($/year)	Labor ($/year)	Selling price ($)	Profit ($)	Profitability ($)
Local	15	180	25	71	30	306	525	219 Either 14.6/Head	71,5
Mixed race	15	324	25	71	30	450	750	300 Either 20/Head	66,6
Large white	15	474	25	71	30	600	1050	450 Either 30/Head	75

This table reveals that, on average, an expense of $1,356 was incurred to maintain the three piglet breeds studied, for a total income of $2,325, generating a profit of $969. This profit is equivalent to approximately $21.53 per piglet. In contrast to the negative profitability of the sires, the profitability observed for the piglets is positive, indicating more efficient management of production costs for this category of animals. This positive profitability also demonstrates that the 9-week period is conducive to optimizing profits for producers, highlighting the importance of short-term piglet management in the pork industry.

Below is a breakdown of the costs incurred for each breed of piglet.

Table 11. Cost breakdown of local breed piglets.

Piglet breed	Feeding piglets ($/2 months)	Cost of transport ration ($/2 months)	Veterinary fees ($/2 months)	Labor ($/2 months)	Total piglet expenditure ($/2 months)
Locale (15)	180	25	71	30	306
%	*58,82*	*8,16*	*23,20*	*9,80*	*100*

For this local breed, we note that the most significant cost item is feed (58.82%), followed by veterinary costs (23.20%), then labor (9.80%), and finally feed transportation costs (8.16%).

Table 12. Cost structure of crossbred piglets

Piglet breed	Feeding piglets ($/2 months)	Cost of transport ration ($/2 months)	Veterinary fees ($/2 months)	Labor ($/2 months)	Total piglet expenditure ($/2 months)
Mixed race (15)	324	25	71	30	450
%	*72*	*5,55*	*15,77*	*6,66*	*100*

For the crossbred breed, we observe that the most important item is feed costs with (72%), followed by veterinary costs with (15.17%), labor is (6.66%) and the ration transportation costs is (5.55%).

Table 13. Cost structure of Large White piglets.

Piglet breed	Feeding piglets ($/2 months)	Cost of transport ration ($/2 months)	Veterinary fees ($/2 months)	Labor ($/2 months)	Total piglet expenditure ($/2 months)
Large White (15)	474	25	71	30	600
%	*79*	*4,16*	*11,83*	*5*	*100*

Regarding the Large White breed, we found that the costs related to feeding were (79%), followed by veterinary costs (11.83%), then labor (5%) and finally the cost of transporting the ration was (4.16%).

10.2.3. Pig Marketing Channel The figure below shows the marketing channels for pigs and their meat in the city of Kindu and its hinterlands.

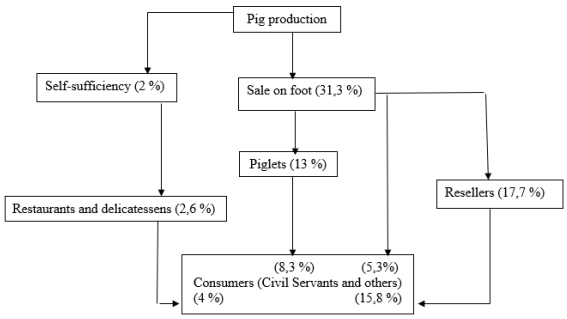


Figure 10: Distribution of actors in the pork product supply chain.

This figure highlights the distribution of actors within the pork product supply chain. It highlights that pork producers or sellers largely dominate this chain, representing 31.3% of the total share. They are followed by resellers with 17.7%, sire producers with 13%, and restaurateurs with 2.6%. End consumers, although the ultimate recipients of the products, represent only a small proportion of the chain, just 2%. These results reflect a structure in which the majority of actors are located upstream, before reaching the final consumer. This distribution of tasks in the value chain elucidates that producers and resellers have a considerable influence on the demand for pork, although restaurateurs and

sire producers also play an important role in regulating supply. The low percentage attributed to end consumers suggests that distribution channels are relatively long, with several intermediaries between producers and end consumers. This complex circuit could lead to additional costs that are reflected in consumer prices, thus impacting the accessibility of pork in these regions.

Optimizing this marketing channel would be an important lever for reducing transaction costs and improving the profitability of the pork industry. This could result in a reduction in intermediaries and better organization of producers into a network to directly reach end consumers. Ultimately, the analysis of zootechnical parameters in pig farming highlights the major role of genetic selection and nutrition in optimizing growth and reproductive performance. The results revealed marked differences between the breeds studied and improved breeds, such as Large White, distinguished by superior morphometric characteristics and significantly higher weight gains, both in sires and piglets. Furthermore, diet also plays a crucial role in the expression of phenotypic traits such as growth, development, reproduction, and resistance to adverse environmental conditions. This study demonstrated that the quality of feed rations has a direct impact on piglet growth. In particular, balanced rations promoted faster weight gain, confirming the importance of formulated and adapted feeds to maximize weight gains and, consequently, optimize the zootechnical performance under study. These results reinforce the fact that rigorous management of livestock management, combined with beneficial genetic selection and balanced feeding, is essential to ensure the profitability and sustainability of pig farms. Thus, to improve performance and maximize producer profitability, it is imperative to consider these key factors in pig farm management, as observed in the context of the study.

11. Discussion of Results

In this study, three hypotheses were formulated to better understand the impact of genetics and nutrition on piglet performance and the economic profitability of pig farms. These hypotheses are: (i) sires from improved breeds, such as Large White, possess superior morphological and reproductive characteristics compared to local breeds; (ii) piglets fed balanced diets and from improved breeds exhibit better livestock performance; and (iii) optimizing livestock management through genetic selection and quality feeding improves the economic profitability of pig farms. The discussion will be structured around three main areas, including: the performance of improved sires, by comparing their morphological and reproductive characteristics with those of local breeds and examining their impact on piglet performance; and the influence of nutrition on piglet livestock performance, by studying the effects of balanced diets on their growth and health. and finally, the economic impact of zootechnical improvement, by evaluating the increased profitability associated with the use of improved breeds and improved feeding conditions.

11.1. Comparative Analysis of the Morphological and Reproductive

Characteristics of the Breeding Stock Comparative evaluation of the breeding stock from improved breeds, particularly the Large White breed, compared to local breeds revealed significant morphological and reproductive differences. The improved breeding stock were distinguished by higher body weight, better anatomical conformation (trunk length, rump width, muscle development), and faster linear growth. These observations corroborate the results of Kambashi et al. (2014), which highlight the morphometric superiority of exotic breeds in Central Africa, particularly in semi-intensive livestock systems. Furthermore, the reproductive performance of the improved breeding stock was found to be superior to that of local breeds. Large White females demonstrated high prolificacy, with a higher average number of piglets per litter, a higher birth survival rate, and better piglet weight gain at weaning. These results are consistent with those reported by Ahozonlin et al. (2010), according to which exotic breeds have a reduced farrowing interval and better reproductive efficiency, provided that management conditions are controlled. The morpho-reproductive performance results from this study confirm the superiority of improved breeds. These results corroborate the observations made by the FAO (2019) according to which, in tropical contexts, improved sires such as Large White can achieve reproductive performance of up to 11 to 13 live-born piglets per litter, compared to 6 to 8 for local breeds. Similarly, Guédégbé et al. (2009) reported that the introduction of selected sires increased productivity per sow by more than 35% in village systems in Benin. However, some authors, such as Dossa et al. (2011), point out that the performance of improved breeds can be influenced by the environment. These authors cited above asserted that under extensive farming conditions, local breeds can better withstand climatic stresses, endemic diseases, and nutritional deficiencies. These factors can reduce the expected benefits of improved breeds if housing, feeding, and veterinary care conditions are not met.

Furthermore, Youssao et al. (2008) emphasize that certain crossbreeding can induce beneficial heterotic effects, combining local hardiness with the productivity of exotic breeds. In the local context of this study, local breeds remain widely used due to their natural resistance to adverse and restrictive environmental conditions and their low maintenance costs. However, a trend toward the gradual introduction of improved breeds by the most dynamic and informed breeders is observed, particularly through untimely crossbreeding in a haphazardly targeted manner. This process, already suggested by Kouakou et al. (2020) in Côte d'Ivoire, aims to reconcile local adaptation and genetic improvement in a logical manner. These results sufficiently prove that parents from improved breeds indeed exhibit more favorable morphological characteristics and superior reproductive performance. These results thus confirm the hypothesis—the first hypothesis of this study—that the selection of improved sires is a determining factor in improving piglet zootechnical performance.This confirmation paves the way for genetic improvement strategies adapted to local realities.

11.2. Influence of Diet on Piglet Zoo technical Performance Diet is an essential factor in the development and performance of piglets.

In the traditional systems observed, feeding is often based on locally available resources (kitchen waste, crop residues, cassava leaves) used without formulation or rationing. This empirically anchored approach leads to significant variability in zootechnical results, particularly in terms of piglet growth, survival, and weaning (Assogba et al., 2020; Koura et al., 2015). Recent studies demonstrate that formulating balanced rations, even using simple local

ingredients, can significantly improve performance. For example, Dossa et al. (2022) showed that sufficient intake of digestible protein in diets leads to faster growth and reduced pre-weaning mortality. Similarly, Houngbo et al. (2019) highlighted that appropriate feeding allows piglets to reach their genetic potential, especially those from improved breeds.

In the context of the study, the gradual introduction of local formulations based on corn bran, cottonseed meal, and fermented cassava flours led to the observation of improved growth performance, litter uniformity, and reduced neonatal losses. These observations are closely related to those of Agbokounou et al. (2021), who emphasize that improved feeding techniques are applicable even in low-resource rural settings, provided they are effectively disseminated. The results obtained are consistent with work conducted in West Africa on family pig systems. This research confirms that better formulated feed, even with modest resources, can significantly improve zootechnical performance (Fall et al., 2016; Dossa et al., 2022). There is strong convergence between this study and the available scientific references. However, some divergences lie in the accessibility of inputs and technical advice: while some authors report rapid adoption of improved practices (Agbokounou et al., 2021), in other contexts, cultural or economic barriers slow this transition (Houngbo et al., 2019). Local feeding practices, although poorly structured, demonstrate adaptation to resources and economic constraints. By integrating them into a participatory extension approach, it is possible to use them as a basis for optimization. Thus, training programs focused on simple ration formulation and the efficient use of local resources could strengthen the sustainability and profitability of village pig farms (Dossa & Houinato, 2022). In light of the results obtained, it can be affirmed that feed plays a decisive role in improving the zootechnical performance of piglets. The comparison between traditional practices and improved approaches shows significant differences in terms of growth, vitality and survival of piglets. These findings thus confirm the hypothesis – the second hypothesis of the present study – that rational feeding, even based on local ingredients, constitutes an essential lever for improving zootechnical performance in village pig systems.

11.3. Economic Profitability of Pig Farming

According to Livestock Practices in Kindu Pig farming in Kindu, as in many regions of sub-Saharan Africa, relies on a variety of livestock practices that directly influence the economic profitability of pig farms. The main factors to consider in this analysis are production and feeding costs, breed selection, and investment and sustainability strategies for pig farming. Production costs in pig farming are mainly divided between the purchase and maintenance of breeding stock and feed costs. Feed-related expenses often represent a significant portion of pig farmers' budgets (Davis & Lungu, 2020). In the case of Kindu, local conditions and limited access to quality feed resources can significantly increase these costs. Dietary choices, whether based on industrial rations or local products, influence not only profitability but also pig health and performance. Optimizing feed costs by combining local ingredients with nutritional supplements could reduce these expenses while maintaining good animal productivity (Fotsing & Nguimkeu, 2019). Evaluating the economic performance of pig farms depends heavily on the type of breed selected and the diet used. Some breeds, such as local breeds adapted to African conditions, may offer higher economic returns due to their ability to adapt to local conditions and consume less expensive feed. However, the use of more productive and specialized breeds could also be considered, but this requires a higher investment in terms of care and feeding (Pomeroy, 2018). In Kindu, profitability could be optimized by choosing a balance between local breeds and improved breeds, taking into account the costs related to their feeding (Lungu & Chama, 2022). The initial investment in pig farming includes the purchase of breeding stock, the construction of infrastructure and the acquisition of necessary equipment. The study of profitability in similar contexts, such as pig farming in sub-Saharan Africa, shows that the initial investment can be high, but that it can be profitable in the medium term thanks to effective management of production costs and continuous improvement of practices. livestock production (Swann & Bwalya, 2017). It is also essential to consider the sustainability of practices. Sustainable livestock systems, which integrate waste management strategies and less expensive local feed, can increase profitability while reducing environmental impact (Bertelsmann Stiftung, 2020). Studies conducted in other parts of Africa, such as Zambia and Uganda, have identified key factors influencing pig farm profitability, including diet type and supplementation strategies (Davis & Lungu, 2020). Comparatively, pig farming in Kindu presents similar challenges in terms of feed costs and breed management, but could benefit from better integration of local practices and support systems such as farmer cooperatives. Such integration could reduce production costs and improve long-term economic returns. The observed divergences between pig farms in different regions may be explained by local factors such as resource availability, market access, and diversity of livestock practices. For example, pig farms in Uganda and Zambia sometimes benefit from better infrastructure and financing conditions than those in Kindu, where producers have limited access to credit and quality resources (Lungu & Chama, 2022). However, similarities in the challenges of broodstock feeding and management suggest that some of the solutions proposed for these neighboring countries could be applied in Kindu, with appropriate adjustments. Local practices in Kindu, regarding broodstock feeding and management, may face challenges due to socioeconomic conditions and limited infrastructure. However, taking into account the recommendations of research on pig farming in sub-Saharan Africa (Fotsing & Nguimkeu, 2019; Bertelsmann Stiftung, 2020), it is possible to adopt a more resilient and viable economic model. This model could combine local traditional practices with elements of sustainability and innovation to create a more profitable livestock system adapted to the Kindu context. The third main hypothesis of this study was confirmed: The improvement of zootechnical practices and more rigorous cost management, particularly through the optimization of feeding and breed choice, contributes to increased profitability of pig farming in Kindu.

11.4. Improving the Zoo technical and Economic Performance of Pig Farming in Kindu

Avenues and Solutions Pig farming, while fundamental to global food security, is often associated with significant environmental impacts, particularly with regard to resource use and greenhouse gas emissions. Sustainable strategies are needed to minimize these impacts while maintaining

productivity. Several studies show that integrating agroecological practices and improved management of production systems can reduce negative impacts while improving yields (Tannous et al., 2018). 5.4.1. Improving Feeding and Resource Management Practices A study published in Science highlights that optimizing animal feed using tailored nutritional formulas and feed supplements reduced in phosphorus and nitrogen can limit environmental impacts while maintaining the profitability of pig production (Bennett et al., 2020). Furthermore, water management, which is essential in drought-prone regions, can be improved by integrating more efficient irrigation systems and reusing water from animal waste for fertilization (Liu et al., 2019).

11.4.1. Use of Clean Technologies and Innovative Management Practices

The adoption of clean technologies in pig production, such as exhaust gas filtration systems and energy production from organic waste (biomethanation), is a rapidly expanding field. Research shows that using biogas to fuel production systems can significantly reduce the carbon footprint of pig farming (Zhao et al., 2021). At the same time, sustainable management practices for grasslands and land used for pig feed production can not only increase productivity but also enhance soil biodiversity. According to a study in Nature Communications, implementing crop rotations and agroforestry systems improves both soil health and the resilience of agricultural ecosystems to climate change (Thomson et al., 2022).

11.4.2. Producer Education and Training

For these practices to be effectively implemented, investment in producer training is necessary. Continuous education on sustainable agricultural practices and livestock management techniques could have significant impacts on the transition to more sustainable systems. Training programs on appropriate technologies, infrastructure improvements, and climate-related risk management have shown positive results in several regions of the world (Smith et al., 2019). Integrating more sustainable livestock practices into the pork industry is essential to ensure food security while minimizing environmental impacts. Recent studies show that the adoption of innovative technologies, combined with more rational management of natural resources, could transform pork farming into a more resilient and environmentally friendly sector. The active involvement of producers, supported by public policies and educational programs, will be key to implementing these changes. To conclude this discussion, the results of this study confirmed the three initial hypotheses regarding pig farming in Kindu. First, the selection of sires from improved breeds, such as the Large White, has proven beneficial in terms of superior morphological and reproductive characteristics, thus contributing to improved piglet performance. Second, rational feeding, even with local ingredients, has proven effective in improving piglet growth, health, and survival, reinforcing the importance of feed management in pig farms. Finally, the optimization of livestock practices, combined with more rigorous management of feed costs and judicious breed selection, has led to a significant improvement in the economic profitability of pig farms in Kindu. Thus, this study highlights the importance of adapting livestock practices to local realities, while introducing continuous improvement strategies to increase the productivity and sustainability of pig farms. The results obtained suggest that the integration of improved breeds and balanced feeding can not only increase zootechnical performance, but also optimize the profitability of livestock farms in the Kindu region, with implications for other similar contexts in sub-Saharan Africa.

12. Conclusion

The aim of this study was to examine the influence of breeds and feed on piglet performance and financial profitability by analyzing pig farming practices in Kindu, focusing on the effects of feeding practices, breed management, and health conditions on piglet performance, as well as the economic profitability of these practices. The ultimate goal was to propose practical recommendations to improve and increase meat productivity and the sustainability of pig farming in this region of the Democratic Republic of Congo, taking into account specific economic and environmental challenges. To achieve this objective, a methodological approach combining descriptive, analytical, and participatory techniques was adopted. Data collection took place from June 15, 2022, to June 15, 2024. It was conducted through direct observations, interviews with local farmers and health authorities, and a documentary review to enrich the information collected. An experimental design was set up in a training piggery, where 45 piglets were divided into three groups, each receiving a different type of ration: local ration, unbalanced ration, and balanced ration. Analyses focused on the piglets' zootechnical performance, the morphological characteristics of the parents, as well as the costs and profitability associated with each feeding management and breed. The results confirmed that balanced feeding has a direct and significant impact on piglet growth. Those fed balanced rations showed greater weight gains than those fed local or unbalanced rations. Piglets from the improved breed (Large White) also exhibited better livestock performance compared to local and crossbred breeds. Furthermore, the analysis of production costs revealed that feed, health management, and breeding costs are the main expenses, but that optimized management of these factors can improve pig farming profitability. The results therefore validated the hypothesis that improved feeding practices and appropriate genetic management lead to increased yields and greater profitability for farmers. The implications of the results are clear: more precise management of feed rations and breeding stock is necessary to improve livestock performance and maximize the profitability of pig farms.

This study also demonstrates that implementing sustainable breeding practices and appropriate genetic selection can overcome the challenges of pig farming in Kindu, while strengthening the sector's resilience to changing economic and environmental conditions. Several avenues can be explored to improve pig farming in Kindu. It is essential to promote the adoption of balanced rations and ongoing training for farmers on feed and health management. Genetic selection of pig breeds, particularly to improve local, crossbred, and Large White breeds, would also be an important lever for increasing productivity while ensuring the sustainability of the sector. Furthermore, financial support for the purchase of quality sires and infrastructure improvements would be crucial for long-term profitability. These actions, combined with better management of natural resources and increased monitoring of health conditions, would substantially improve the efficiency of pig farming in Kindu. Finally, this study opens the door to several avenues for future research. In-depth studies on the long-term effects of

different feeding practices and genetic selection on pig reproduction, longevity, and health would be beneficial. It would also be relevant to explore the integration of agroecological systems into pig farming, particularly by exploring the use of combined cropping or agroforestry practices to reduce environmental impact. Furthermore, the implementation of modern technologies for pig farm management, such as automated health and feed monitoring systems, could offer new opportunities to improve the sector's efficiency and profitability. This research will deepen knowledge on pig farming practices adapted to local contexts and could contribute to the promotion of a more sustainable and resilient pig sector in the DRC. This study shows that improving increasingly balanced feeding, genetic management of pig breeds, and optimizing animal health management are necessary incentives for the productivity and profitability of pig farms in Kindu. The results obtained provide a solid basis for the implementation of sustainable strategies that will improve the economic performance of breeders while limiting environmental impact.

This conclusion also opens promising perspectives for future research, thus contributing to the sustainability of pig farming in the region and beyond, in the Democratic Republic of Congo.

Bibliographic references

1. Abdallah-Nguertoum E., 2010. Pig Farming in the Peri-Urban Region of Bangui (Central African Republic). Doctoral Thesis, Inter-State School of Veterinary Sciences and Medicine, Dakar, Senegal, 111p.
2. Aboki S.S., 2011. Characteristics of the Processing and Consumption Sectors of the Pork Meat Industry in the Ouémé and Zou Departments of Benin. Thesis Report for the Professional Bachelor's Degree. Department of Animal Production and Health. EPAC/UAC, Benin. 45p.
3. Adamou-N'diaye M., Gbangboche A.B., Adjovi A., Hanzen C.H., 2000. Spermatic characteristics of Borgou bulls in Benin. Annals of Agricultural Sciences of Benin, 1 (2): pp.71-83, 2000.
4. Agbokounou A.M., 2001. Study of the energy and protein requirements of local Beninese pigs in the starter-growth phase. DEA (Master of Science in Animal Science), Faculty of Agricultural Sciences of Gembloux, Belgium, 92 p.
5. Agbokounou A.M., Ahounou G.S., Youssao I.A.K., Mensah G.A., Koutinhouin B., Hornick J-L., 2016. Breeding characteristics of Africans' local pigs. Journal of Animal & Plant Sciences (JAPS), 30(1): pp. 4701-4713. Agronomist, National University of Benin, Cotonou, 152 p.
6. Anugwa FOI and Okwori AI, 2018. Performance of Growing Pigs of Different Genetic Groups Fed Varying Dietary Protein Levels. African Journal of Biotechnology 7: pp. 2665-2670.
7. Audiot A., 1995. Breeds of Yesterday for the Livestock of Tomorrow, INRA Editions, Collection Espaces Ruraux, BRG, CPBR Midi-Pyrénées, Federation of Regional Natural Parks of France, 229 p.
8. Audiot A., Rosset O., 2004. Local Breeds Between Conservation and Promotion, in Guintard C. Mazzoli-Guintard C. (eds.), Breeding of Yesterday, Breeding of Today, a Mixture of Ethnozootechnie Offered to Bernard Denis. Presses Universitaires de Rennes. p. 161-Ayizanga R.A., 2016. Phenotypic Characterization and Genetic Diversity of the Local Pig of Ghana. Doctor of Philosophy. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, April 2016, 145 p.
9. Ayssiwèdé S.B., 2004. The pork industry in Benin: production, marketing, proposals for improvement and development prospects. Dakar, Senegal, Inter-State School of Veterinary Sciences and Medicine, 120 p.
10. Bondombe, W.Y., and Bolembe, L., 2018. Problems of Marketing Eggs Sold in Kisangani, DRC. Ann. Ifa-Yangambi, Vol. 2 (2): pp. 67-84
11. Bondombe, w.y., 2018. Identification of ticks infesting cattle raised in Kisangani and its surroundings. Ann.IFA-Yangambi, vol. 1 (1): pp. 85-99.
12. Carter N., Dewey C., Mutua F., de Lange C., Grace D., 2013. Average daily gain of local pigs on rural and peri-urban smallholder farms in two districts of Western Kenya. Tropical Animal Health Production 45: pp. 1533–1538.
13. CIRAD, 2021. Foundations for silviculture in dense tropical rainforests in Africa. CIRAD, FORAFRI. 387p.
14. Codjo A.B., 2003. Estimation of the energy requirements of local pigs in Benin growing between 7 and 22 kg live weight. Tropicultura, 21: pp. 56-60.
15. D'Orgeval R., 1997. The Development of Pig Farming in Africa: Analysis of Local African Pig Farming Systems in Southern Benin. Doctoral Thesis from the National Institute of Agronomy, Paris Grignon, 273 p.
16. Deka E., 2008. 2nd International Conference of the "Agricultural and Rural Training" (FAR) Network "Role of Stakeholders in the Orientation and Operation of Rural Training Systems for Development" TUNIS - May 19-23, 2008, 6p.
17. Djimènou D., 2010. Typology of Pig Farms in Subhumid Zones of Benin. Master's Thesis in Animal Production and Health, Department of Animal Production and Health, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Benin. 94p.
18. Djimènou D., Adoukonou-Sagbadja H., Chrysostome C., Koudande O.D., 2018b. Phenotypic characterization of local pigs (Sus scrofa domesticus) in southern Benin. J.Anim. Plant Sci., 37(1): pp.5956-5974.
19. Djimènou D., Adoukonou-Sagbadja H., Chrysostome C., Koudandé O.D., 2018a. Processing and marketing of pork in southern Benin: characteristics and economic challenges. 4th International Conference of the University of Parakou, November 28-30, 2018. University of Parakou, Benin.
20. Djimènou D., Adoukonou-Sagbadja H., Chrysostome C., Koudandé O.D., 2018c. Uses of pigs and pig products in human nutrition and socio-culturally in southern Benin, 18th edition of the International Scientific Days of Lomé (JSIL),

from October 8 to 12, 2018, University of Lomé, Togo.
21. Djimènou D., Adoukonou-Sagbadja H., Chrysostome C., Koudandé O.D., 2018d. Study of the structure and genetic distances within the pig population in southern Benin using microsatellite markers. 18th edition of the International Scientific Days of Lomé (JSIL), from October 8 to 12, 2018, University of Lomé, Togo.
22. Djimènou D., Adoukonou-Sagbadja H., Koudandé O.D., Chrysostome C., Hounzangbé Adoté S., Agbangla C., 2017. Sociodemographic characteristics of pig (Sus scrofa domesticus) breeders and pig herd structure in southern Benin. Int.
23. Djimènou D., Adoukonou-Sagbadja H., Koudandé O.D., Chrysostome C., Hounzangbé Adote S., Agbangla C., 2017. Characteristics and constraints of pig breeding in the sub-humid zone of Benin. Int. J. Curr. Res. Biosci Plant Biol., 4(11): pp.38-49, doi:https://doi.org/10.20546/ijcrbp.2017.411.006 1:30 p.m.
24. Do Duc L., 2013. Genetic and zootechnical traits of stress-negative Pietrain pigs in crossbreeding with exotic and local sows in Northern Vietnam. Doctoral thesis in Veterinary Sciences. Faculty of Veterinary Medicine, University of Liège, 160p.
25. Edoukou 2012: Swine Sector, Democratic Republic of Congo. National Livestock Reviews of the FAO Animal Production and Health Division. No. 2. Rome. Draft Animal Health Code in the DRC, 71p.
26. Edoukou G. Djassi 2012. Pig Sector, Democratic Republic of Congo. National Livestock Reviews of the FAO Animal Production and Health Division. No. 2. Rome, 32p.
27. Erxleben, 1777. Obtained a medical degree in 1767 from the Georg-Augusta University of Göttingen. There he taught physics and chemistry. He published Anfangsgründe der Naturlehre and Systema regni animalis (1777).
28. FAO, 2000. World Watch List for domestic animal diversity. 3rd edition. Edited by Beate D. Scherf. Rome, 726p.
29. FAO, 2006. The State of the World's Animal Genetic Resources for Food and Agriculture. 1st ed. Rome: FAO.
30. FAO, 2013. Phenotypic Characterization of Animal Genetic Resources. Strategies on Animal Production and Health, No. 11. Rome. Translation: Vanessa Board. Technical revision of the text: Xavier Rognon. French edition, 151p.
31. Georges D. Edoukou, 2003. African Swine Fever: Global Situation – Epidemiology – Clinical Study and Diagnosis, FAO, 13p.
32. Gizaw S., Getachew T., Edea Z., Mirkena T., Duguma G., Tibbo M., Rischkowsky B., Mwai O., Dessie T., Wurzinger M., Solkner J., Haile A., 2013. Characterization of indigenous breeding strategies of the sheep farming communities of Ethiopia: A basis for designing community based breeding programs. ICARDA working paper, Aleppo, Syria, 47p.
33. Gouttenoire L., Hostiou N., Taverne M., 2010. Participatory Research on Farms and Territories: Innovative Approaches. ISDA, Montpellier, June 28-30.
34. Halimani T.E., Muchadeyi F.C, Chimonyo M., Dzama K., 2010. Pig genetic resource conservation, the Southern African Perspective. Ecological Economics, 69: pp. 944-951.
35. Halimani T.E., Muchadeyi F.C., Chimonyo M., Dzama K., 2012. Some insights into
36. Herrero M., Havlik P., Mc-Intire J., Palazzo A., Valin H., 2014. The Future of African Livestock: Realizing the Potential of Livestock for Food Security, Poverty Reduction, and Environmental Protection in Sub-Saharan Africa. Office of the United Nations Special Representative for Food and Nutrition Security and the United Nations System Influenza Coordinator (UNSIC), Geneva, Switzerland, 118 p.
37. Houndonougbo M.F., Adjolohoun S., Aboh B.A., Singbo A., Chrysostome C.A.A.M. 2012. Characteristics of the pig farming system in southeastern Benin. Bull. Rec. Agr. Benin (BRAB). Special issue Livestock & Wildlife: pp. 15-21.
38. Jarvis D.I., Padoch C., Cooper Y.H.D., 2012. Biodiversity Management in Agricultural Systems. Chap. 6: Management of Zogenetic Resources: Variation and Interaction. Published by Bioversity International. pp. 149-191.
39. Lebret. 2016. Modulation of pork quality by diet. Prod. Anim. 22: pp. 33-40.
40. Leroy P. and Elsen J.M., 2000. Principles of using genetic markers to detect genes influencing quantitative traits. INRA Animal Productions, special issue "Molecular genetics: principle and application of animal populations", pp.211-215.
41. Leroy P., Moula N., Huart A., Leroy E., Cassart R., Ruppol P., Levrard O., Fadili M. E., Binh D.V., Thang N.V., Duc L.D., N Fundiko D., Nienhaus B., Antoine Moussiaux N., Farnir F., 2012. Improvement of the genetic performance of tropical breeds by Walloon breeds. 15th Overseas Day, August 25, 2012 Espace Senghor, Gembloux Agro-Bio Tech. 24p.
42. Mopaté L.Y., 2000. Pig farming on two reference village plots (Ngoko and Tchanar) in the savannah zone of Chad. Technical Survey Report, N'Djamena, Chad, Farcha Laboratory, pp. 8-13.
43. Mopaté L.Y., 2002. Productivity of Pig Farms in the Departments of Logone Occidental, Mayo-Dallah, and Kabia in the Sudanian Zone of Chad. Mission Report. N'Djamena, Chad, Lrvz, 15p.
44. Mopate L.Y., 2008. Dynamics of Pig Farms and Improving Production in Urban and Peri-Urban Areas of N'Djamena (Chad). Single Doctoral Thesis in Integrated Natural Resource Management (GIRN), Specialization: Animal Production, Polytechnic University of Bobo-Dioulasso (UPB), Burkina Faso, 245p.
45. Mopate L.Y., Kabore-Zoungrana C.Y., Facho B., 2011. Herd Structure and Performance of Pig Farms in the N'Djamena Area of Chad. Int. J. Biol.Chem. Sci., 5: pp. 321-330.
46. Mopaté L.Y., Kaboré-Zoungrana C-Y., 2009. Livestock Dynamics and Characteristics of Pig

Producers in the City of N'Djamena, Chad. Author's Manuscript, published in "African Savannas in Development: Innovating to Last, Garoua: Cameroon (2009)", CIRAD-00472076, version 1 - 9 Apr 2010. 10p.
47. Mopaté L.Y., Kaboré-Zoungrana C-Y., 2010. Livestock dynamics and characteristics of pig producers in the city of N'Djamena, Chad. In: Jamin, J.Y., Seyni Boukar L., Floret C., (eds), Proceedings of the conference "African Savannas in Development: Innovating to Sustain," April 20-23, 2009, Garoua, Cameroon, 9p.
48. Mopaté L.Y., Koussou M.O., 2002. Pig farming: an ignored but well-established livestock sector in rural and peri-urban agrosystems in Chad. In: Jamin J.Y., Seyni Boukar L., Floret C., (eds.), Proceedings of the conference "African Savannahs: Changing Spaces, Actors Facing New Challenges", Garoua, Cameroon, May 27-31, 2002, 9 p.
49. Mopate L.Y., Koussou M.O., 2003. Pig Farming: An Ignored Yet Well-established Livestock Farm in Rural and Peri-urban Agrosystems of Chad. In: Jamin J.Y., Seyni Boukar L. and Floret C. (eds., CD-ROM), Proceedings of the conference "African Savannahs: Changing Spaces, Actors Facing New Challenges", Garoua, Cameroon, May 27-31, 2002, 9 p.
50. Mopaté L.Y., Koussou M.O., Kabore-Zoungrana C.Y., Gouro A., 2006a. Trade and consumption of pork in the N'Djamena area (Chad). Senegalese Journal of Agricultural and Agri-Food Research, 1 (02), pp.39-48.
51. Mopaté L.Y., Koussou M.O., Nguertoum E.T., Ngo-Tama A.C., Lakouetene T., Awa D.N., Mal H.E., 2010. Characteristics and performance of urban and peri-urban pig farms in the savannahs of Central Africa: the case of the cities of Garoua, Pala and Bangui. In: Jamin J.Y., Seyni-Boukar L., Floret C., (eds), Proceedings of the conference "African savannas in development: innovating to last", 20-23 April 2009, Garoua, Cameroon, 9p.
52. Mopaté Y.L., Koussou M.O., Kaboré-Zoungrana C.Y., 2006b. Pig farming in Chad: Assessment of the introduction, improvement and dissemination of exotic breeds, AGRI, 38: pp. 87-98.
53. Mukandama, Mwanasaka, and Myonge, 2020. Characterization of pig farming (sus domesticus) and its economic impact in Maniema Province. DR Congo. D.E.S / FGRNR. University of Kisangani.
54. Muys D., Westenbrink G., Meinderts J., 2003. Pig Farming in Tropical Zones. Agrodok Series No. 1, Agromisa, Wagaeningen, 85p.
55. Nahar N., Uddin M., Gurley E.S., Hossain M.J., Sultana R., Luby S.P., 2015. Cultural
56. Ndébi G., Kamajou J., Ongla J., 2009. Analysis of constraints to the development of pig production in Cameroon. Tropicultura, 27(2) pp. 70-76.
57. Ndébi G., Ongla J., 2006. Operation of pork distribution systems in Cameroon. Tropicultura. 24(2): pp. 73-81.
58. Nonfon W.R., Deka E., Adégbidi A., Codjo B., 1994. Local Pig Farming in Benin. Report I: Diagnostic Surveys on Livestock Systems and Marketing Sector. Volume I: Livestock System. FSA/UNB. 146p.
59. Nonfon W.R., Deka E., Adegbidji A., Codjo B., Chrysostome C., 2000. Improving the Productivity of Local Pigs in Southern Benin. Final Technical Report. Cotonou, Benin, National University of Benin/FSA. 174p.
60. Onadambo N., 2015. Socioeconomic Impacts of the Use of Wild Fauna and Flora on the Daily Lives of Populations Living Near the Kaïlo Forest Reserve in Maniema Province/DR Congo, unpublished thesis, University of Kisangani, 59p.
61. Rai A.K., Palni U., Tamang J.P., 2009. Traditional knowledge of the Himalayan people on production of indigenous meat products. Indian Journal of Traditional Knowledge, 8(1): pp.104-109.
62. Sogbossi O.S., 2015. Morphobiometric Characterization and Productivity of Local Pig Females (Sus scrofa domesticus) in Southern Benin: Case of the Municipalities of Abomey-Calavi, Djakotomey, and Lokossa. Master's Thesis, Department of Animal Production, Faculty of Agricultural Sciences, University of Abomey-Calavi, Benin. 80p.
63. Soleimani, A. F., I. Zulkifli, A. R. Omar and A. R. Raha, 2011 Physiological responses of 3 chicken breeds to acute heat stress. Poultry Science 90: pp.1435-1440.
64. Tchoumboué J., 1983. Limiting factors of small-scale intensive pig and poultry farming in Cameroon. Rev. Elev. Med. Vet. Pays Trop., 36(4): pp. 409-413. The phenotypic and genetic diversity of indigenous pigs in southern Africa. S. Afr.
65. Tibbo M., 2006. Productivity and Health of Indigenous Sheep Breeds and Crossbreds in the Central Ethiopian Highlands. Doctoral thesis. Swedish University of Agricultural Sciences Uppsala. ISSN 1652-6880, ISBN 91-576-7100-1. 76p.
66. EU, 2013. Agricultural Genetic Resources: From Conservation to Sustainable Use. Report from the Commission to the European Parliament, the Council, and the European Economic and Social Committee. Brussels, 28.11.2013. European Commission. 15p.
67. Umutoni C., 2012. Technical and economic assessment of pig farms in Bobo Dioulasso (Burkina Faso). Master's thesis in Animal Production and Sustainable Development, Inter-State School of Veterinary Sciences and Medicine (EISMV), Dakar. 45p.
68. Wiener G., Rouvier R., 2009. Animal genetic improvement. Tropical Agriculture in your pocket. Series editor: Philippe Lhoste. Edition Quæ, CTA, PAG. Translated by Anya Cockle. 283p.
69. Youssao A.K.I., Verleyen V., Michaux C., Clinquart A., Leroy P.L., 2002. Carcass composition, meat quality, and exploitation of the stress-negative Piétrain. Ann. Médecine Vét., 146 pp. 329-338.
70. Youssao A.K.I., 2015. National Genetic Improvement Program. Dairy and Meat Sector Support Project (PAFILAV), FAD, Benin, 323p.

71. Youssao A.K.I., Koutinhouin G.B., Kpodekon T.M., Bonou A.G., Adjakpa A., Dotcho C.D.G., Atodjinou F.T.R., 2008a. Pig production and local genetic resources in the peri-urban areas of Cotonou and Abomey-Calavi in Benin. Animal Resources Review Livestock. Med. vet. Trop. Countries, 61 (3-4): pp.235-243.
72. Youssao A.K.I., Koutinhouin G.B., Kpodékon T.M., Yacoubou A., Bonou A.G., Adjapka A., Ahounou S., Taiwo R., 2009a. Genetic improvement of the zootechnical performance of the local pig of Benin by crossing with the Large-White. Int. J. Biol. Chem. Sci., 3: pp. 653-662.
73. Youssao A.K.I., Kpodékon T.M., Koutinhouin G.B., Adjapka A., Yacoubou A., Ahounou S., 2008b. Influence of male castration on growth performance, carcass characteristics and meat qualities of the local pig of Benin. Bulletin of Agricultural Research of Benin, 61: pp. 1-24. 164. Youssao A.K.I., Mourot J., Edénakpo A., 2004a. Effect of rearing method on carcass and meat characteristics of local pigs in Benin. 10th Muscle Science and Technology Day (JSMTV), pp. 153-154.
74. Youssao I.A.K., Tobada P.C., Koutinhouin B.G., Dahouda M., Idrissou N.D., Bonou G.A., Tougan U.P., Ahounou S., Yapi-Gnaoré V., Kayang B.X.R. and TixierBoichard D.M., 2010. Phenotypic characterization and molecular polymorphism of indigenous poultry populations of the species Gallus gallus of Savannah and Forest ecotypes of Benin. African Journal of Biotechnology, 9: pp. 369-381. Available online at: http://www.academicjournals.org/AJB.
75. Youssao I.K.A., Mourot J., Gbangboche A.B., Adehan R., Akoutey A., Edenakpo A., 2004b. Influence of Diet on Growth Performance and Carcass Characteristics of Local Breed Pigs in Benin. RASPA, 2: pp. 31-36.
76. Yuma. M., 2018. Informal Logging: Patterns, Implementation Approach, and Participatory Sustainable Management Strategies to Curb Deforestation in the Kindu Hinterland (Maniema, DR Congo). D.E.S / FGRNR. University of Kisangani. 77 p.