Smallholder pig production systems along a periurban-rural gradient in the Western provinces of the Democratic Republic of the Congo

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Published in the Journal of Agriculture and Rural Development in the Tropics and Subtropics (2014), vol 115, p 9-22 http://www.jarts.info/index.php/jarts/article/view/2014020344851

Abstract

In the Democratic Republic of the Congo (DRC), pigs are raised almost exclusively by smallholders either in periurban areas of major cities such as Kinshasa or in rural villages. Unfortunately, little information is available regarding pig production in the Western part of the DRC, wherefore a survey was carried out to characterize and compare 319 pig production systems in their management and feeding strategies, along a periurban - rural gradient in Western provinces of the DRC. Pig breeding was the main source of income (43 %) and half of respondent were active in mixed pig and crop production, mainly vegetable garden. Depending on the location, smallholders owned on average 18 pigs, including four sows. Piglet mortality rate varied from 9.5 to 21.8% while average weaned age ranged between 2.2 and 2.8 months. The major causes of mortality reported by the farmers were African swine fever 98%, Swine erysipelas (60%), erysipelas trypanosomiasis (31 %), Swine worm infection (17 %), and diarrhoea (12 %). The majority of the pigs were reared in pens without free roaming and fed essentially with locally available by-products and forage plants whose nature varied according with the location of the farm. The pig production systems depended on the local environment; particularly in terms of workforces, herd structure and characteristics, production parameters, pig building materials, selling price and in feed resources. It can be

concluded that an improvement of Congolese pig production systems should consider (1) a reduction of inbreeding, (2) an improvement in biosafety to reduce the incidence of African swine fever and the spread of other diseases, and (3) an improvement in feeding practices.

Keywords: Pig rearing; Smallholder farming; Feeding strategies; Health

1. Introduction

Raising pigs plays an important role in many tropical countries. Smallholder farming systems improve livelihood and food security for the poorest people (Dixon et al., 2001; Keoboualapheth and Mikled, 2003; Kumaresan *et al.*, 2007). In addition to providing protein for human consumption, pigs are often one of the main sources of cash income in rural areas and provide manure for cropping (Le Van *et al*., 2004).

In the Democratic Republic of the Congo (DRC), pigs are raised almost exclusively by smallholders either in periurban areas of major cities such as Kinshasa or in rural villages. Industrial pig production is barely developed (CAVTK, 2003). According to different reports it appears that there are an increasing number of small and medium size semi-intensive pig-keeping enterprises at the expense of intensive pig farms in and around towns and cities (CAVTK, 2003; NEPAD & FAO, 2006). This situation is probably related to the political situation. The lack of employment caused by the wars of 1996-1998, the steady insecurity in the eastern part of the country, the injustice in the distribution of national wealth, etc. have encouraged the practice of informal activities including pig breeding. This informal economy in general, and pig production in particular promotes greater self-sufficiency, provides a greater food security to urban households (Mougeot, 2000) and increases incomes. Nonetheless, pig farms are under the influence of variables laying constraints or offering opportunities that vary according to the location of the farm. This is likely to yield variability in the production systems that will possibly reflect in differing needs regarding development programs. For instance, periurban sites in Kinshasa have an easier access to profitable markets, commercial concentrates and agro-industrial by-products while rural producers do not have all of these three aforementioned advantages. However, pig farmer in rural sites have the opportunity to obtain agricultural products such as cassava and maize at an affordable price.

The absence of profitable market is due to people's poverty, suitable means of transformation and the high costs of product transportation to Kinshasa and its approximately eight millions of potential customers. Taking actions in order to make the pig rearing activity more efficient and sustainable requires the availability of data on its management in order to address the major constraints laid on pig smallholders. Unfortunately, little information is available regarding pig production in the Western part of the DRC, wherefore this study aims at characterizing and comparing smallholder pig production systems along a periurban - rural gradient of the Kinshasa and the Bas-Congo province. More specifically, this work focuses on feed resources, feeding management, breeding system, productivity and sanitary issues of pig production systems by considering differences in resources and constraints on local scale.

2. Materials and methods

A survey was conducted in four periurban municipalities of Kinshasa and in four rural areas in the Bas-Congo Province. The four periurban municipalities were N'djili (N'djili), Kimbanseke (Kimba), Mont-Ngafula (Mont), and N'sele (N'sele) (4° 19′ 19″ S 15° 19′ 16″ E). N'djili and Kimbanseke are located to the southeast of Kinshasa, N'sele to the east and Mont-Ngafula to southwest. These four municipalities cover an area of 11.4, 273.8, 358.9 and 273.8 km², with 29123, 2495, 630 and 176 inhabitant per km² respectively for N'djili, Kimbanseke, Mont-Ngafula and N'sele. Except for N'djili, the other three sites are considered as periurban municipalities characterized by intense agriculture and husbandry and related activities including firewood exploitation and harvest of caterpillars, nuts, exotic fruits, mushrooms, raffia and palm wine, ferns and others (Biloso Moyene, 2008). N'djili is located more in the middle of the city. However, the presence of an agricultural perimeter with lower population density along the N'djili river favoured the installation of numerous small pig farms. The four rural areas that were surveyed in the Bas-Congo Province are Kasangulu (Kasang : 4° 43 '24'' S, 15 ° 17' 23'' E), Kisantu (Kisan: 5° 7' 25'' S, 15° 5' 46'' E), Mbanza-Ngungu (Mbanza: 5° 20' 23'' S, 14° 50' 14'' E) and Boma (Boma: 5 ° 46 '40''S, 13 ° 6' 32''E). All eight sites were selected because they are known for having a high density of pig farms. They have almost the same climate, characterised by a rainy season of eight months from mid-September to mid-May with a drop in rainfall between December and February and a dry season of

four months extending from mid-May to mid-September. The average annual temperature is 25 °C and the relative humidity is 79% (Department of Land Affairs, Environment, Nature Conservation, Fisheries and Forestry, 1999).

2.1. Survey organisation

The present study involved surveys and direct on site observations from July 13 to September 13 2010. Only smallholders showing over 1.5 years of experience in pig production were considered. A total of 319 farmers were interviewed, 40 smallholders in each site except Kasangulu where only 39 farmers were interviewed. Smallholders were randomly selected on the basis of a list obtained either from farmers associations or local authorities. Lists from different sources were merged per surveyed site and farmers were continuously numbered. Numbers were randomly drawn until the sample size was reached.

Four agricultural engineers were trained for the survey before going on field. They were trained to use spring scales. The questionnaire had previously been tested by surveyors in farms located in the valley of the Funa (Kinshasa). The results of this pre-survey are not included in this paper. The questionnaire was administered in a single pass. The technique of data collection consisted of questions followed by a discussion when needed for clarity in relation to breed, names of plants and their use and the common causes of death. The questionnaire had six main sections including the characterisation of the farm organisation and household, breeding management and productivity parameters, feed resources and feeding strategies, housing conditions, health issues and marketing. Where farmers had their own records of pigs' weight, those data were used in this study. If not, when animals of both categories considered for weight data (around weaning and around first mating) were present on the farm at least three animals for each category were weighed by the farmer with spring scales provided by the surveyors to serve as reference to estimate the weight of the others pigs. The weight of an animal was accepted only when surveyors and farmer's estimations agreed. If not, that animal was also weighed. Questions regarding feeding systems were open questions in order to allow the farmer to give enough details about his system.

2.2. Survey statistical analysis

Chi-squared analyses were used to test the independence of variable between survey sites using SPSS. The MIXED procedure of SAS was performed to compare means of quantitative data between sites. Correspondence analysis of SAS was used to study the reconciliation between the sites location and the ingredients fed to the pigs.

3. Results

3.1. Family structure and organization people

The nucleus family was composed of 5.9 to 7.5 people on average (Table 1). Pig breeding was either a male (47%) or a family-run business (42 %). Few pig farms were under the supervision of women (11 %). No effect of the location was found in terms of family composition (P>0.05). However, workforces, mains sources of income and children's participation in the activity were dependent on the location (P<0.001). In Kisantu and Kasangulu the caretaking of pigs was performed almost exclusively by men who were the head of the households, while in Mbanza-Ngunu the whole family was involved in this activity. Family members were the major contributors to the farm workforce, while hired workers were on average present in 35 % of the farms.

Table 1 Family structure and farm organization of smallholder pig production systems in the Western provinces of the Democratic Republic of the Congo (% of households) (n=40 per site). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo				Mean
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan	percentage
Family size (χ^2,P=0.069)[1]									
Lowest through 5	26	24	50	29	23	16	41	35	31
6 to10	64	71	47	66	73	76	42	60	62
More than 10	10	5	3	5	5	8	17	5	7
Average size of households	7.3	6.8	5.9	6.5	6.8	7.5	6.7	6.1	

Workforces (χ^2, P=0.001)									
Family	58	62	49	58	100	61	43	85	65
Hired workers	42	38	51	42	0	39	57	15	35
Rearing and feeding (χ^2,P<0.001)									
Men	40	26	51	68	17	3	80	90	47
Women	12	6	5	11	30	8	7	5	11
All Familly	46	68	44	21	53	89	13	5	42

3.2. Level of specialisation

The level of specialisation of smallholders varied (P<0.001) according to location and province. Among them, some combined cropping and pig production, others were merely breeders while the majority had formal or informal activities in addition to agriculture (Table 2). Nevertheless, pig breeding was the main source of income of most farmers, followed by cropping and other off-farm activities such as a formal job (Table 2). The types of agricultural crop were mostly vegetable crops and cassava (7 %), except in Boma (P<0.001) Farmers (21 %) also owned other animal species, mainly indigenous chicken (32 %), ducks (28 %), goats (14 %) and sheep (8 %). Farms were often located near water points (stream and pond).

Table 2 Farmer speciality and main source of income of smallholder pig production systems in the Democratic Republic of Congo (% of households) (n=40 per site). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
Specialty (χ^2,P<0.001)[1]								
Pig production	17.5	2.6	10.3	20.5	2.6	7.3	13.8	5.1
Pig production and cropping	20.0	53.8	51.3	9.1	10.3	14.6	10.3	23.1
Pig production, cropping and others activities	62.5	43.6	38.4	70.4	87.1	78.1	75.9	71.8
Main source of income (χ^2,P=0.042)								

Pig production	39.6	45.2	44.1	47.7	48.1	47.7	38.8	31.2
Cropping	20.9	36.9	35.5	26.1	8.6	12.8	16.5	28.6
Salary, petty trade and donation	39.5	17.9	20.4	26.2	43.3	39.5	44.7	40.2
Agricultural crops (χ^2,P<0.001)								
Vegetables	88.0	96.7	100	95.5	33.3	100	82.4	59.5
Food crops	12.0	3.3	0	4.5	66.7	0	17.6	40.5

3.3. Herd structure and characteristics

The average number of pigs per farm was 17.9±0.9 for the 319 farms and varied from 12.4 in Boma to 25.4 in Kasangulu (Table 3). The average number of sows, litter size and weaned piglets was different between sites and varied from 2.6 to 4.6, 7.4 to 9.7 and 6.7 to 8.5, respectively. Pre-weaning mortality rates varied from 9.5 to 21.8 % between sites. The age of the piglets at weaning ranged between 2.2 and 2.8 months according to the site. Globally, piglets were weaned on an average age of 2.5 months but between 1.5 and 2 months in 70 % of the cases. At that stage, piglet's weight ranges about 7.9 and 11.7 kg. However, when post-weaning feed was lacking, the breeder may keep piglets suckling for up to 4 months. First mating occurred when the gilt was about 7.3 to 8.9 months old but male first mating depended more on its weight rather than its age., Although this parameter was not constant across the different locations that were surveyed, reform of sows was practiced early. Indeed, on average,, 76% of the farmers reformed sows not later than after the third parturition. Boars were not kept for a long time either as they were sold before they reached the age of 3 years of use in 71.0 % of the farms (Table 4).

Table 3 Reproductive performance, birth and weaning litter size of 319 smallholder pig production systems in the Western provinces of the Democratic Republic of the Congo (% of households) (n=40 per site). [1]In a row, means followed by a different letter differ at a significance level of 0.05

	Kinshasa				Bas-Congo							
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan				P values of sites
					Mean				Min	Max	S.E.M	effect
Number of pigs per farm	14,5[a1]	14,7[a]	22,2[bc]	18,5[ab]	12,4[a]	23,2[bc]	25,4[c]	12,7[a]	2,0	102,0	0,86	<.001
Number of sows per farm	3,1[a]	3,9[a]	4,5[b]	4,0[ab]	4,0[ab]	4,6[b]	5,3[b]	2,6[a]	1	25	0,18	<.05
Number of boars per farm	0,5[a]	0,7[a]	0,9[ab]	0,7[a]	1,1[b]	0,7[a]	1,2[b]	0,6[a]	0	4	0,04	<.001
Gilt weight at first mating (kg)	50,3[b]	52,9[bc]	50,7[b]	52,1[bc]	43,6[a]	43,1[a]	56.2[c]	45,8	35	90	0,54	<.001
Gilt age at first mating (month)	7,3[a]	8,2[ab]	8,1[a]	8,7[b]	7,8[a]	8,5[b]	7,3[a]	8,9[b]	5	12	0.09	<.001
Boar weight at first mating (kg)	55,4	57,2	55,0	53,8	53,9	57,0	57,6	53,5	40	90	0.72	0.083
Boar age at first mating (month)	8,4[ab]	8,8[b]	9,1[b]	8,9[b]	8,8[b]	11,1[c]	7,5[a]	9,7	6	18	0,14	<.001
Piglets born alive per litter	8,0[ab]	8,7[b]	8,6[b]	8,7[b]	7,4[a]	9,6[c]	9,7[c]	7,6[a]	4	12	0,11	<.001
Piglets weaned per litter	7,0[a]	7,4[a]	7,7[ab]	6,8[a]	6,7[a]	8,0[b]	8,5[b]	6,7[a]	3	12	0,11	<.001
Age at weaning (month)	2,3[a]	2,2[a]	2,2[a]	2,2[a]	2,8[b]	2,3[a]	2,2[a]	2,4[a]	2	4	0,03	<.001
Weight at weaning (kg)	8,6[b]	7,9[a]	8,6[b]	9,2[c]	8,0[a]	9,9[c]	11,7[d]	8,1[ab]	4	15	0,15	<.001

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3.4. Breeds

It was difficult to identify the actual proportions of the different breeds of pigs found in the study area. According to the statements of the breeders, it would be Large White, Piétrain, local pork (large black), Landrace and hybrids resulting from local breeds crossed with exotic breeds. However, some animals considered as Large White or Piétrain did not show all the phenotypical characteristics of these breeds while others had offsprings with highly diversified phenotypical characteristics (dress color, shape of the ears and the profile of the back of the animal). The most prevalent dress colors were white, spotted black and black.

Table 4 Phenotypical characteristics of pigs of 319 smallholder pig production systems in the Democratic Republic of Congo (% of response). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
Dress color (χ^2,P<0.0001)[1]								
White	63,9	61,8	58,7	59,7	84,4	65,6	50,9	62,6
Black	6,6	18,2	17,5	9,7	0	32,8	12,3	14,2
Spotted black	31,1	27,3	23,8	33,9	15,6	1,6	36,8	24,9

3.5. Reproductive management

Breeding systems were very similar among smallholders. They can be assimilated to a "breeder-fattener" structure. Farmers bred sows and their piglets until the fattening pigs reached the expected slaughter weight. However, they sometimes sold weaned piglets. Sometimes sows and boars were never really reformed but sold before they reached the end of their reproductive career (Table 5). The number of farmers who own at least one boar varied from one location to the other (P<0.001). Nsele displayed to lowest rate of boar presence with 37% while Boma the highest (88%). In the other locations, boars were present, in 62, 65, 57, 56, 74 and 59 % of the farms, for N'djili, Kimbanseke, Mont-Ngafula, Mbanza-Ngungu, Kasangulu and Kisantu, respectively The other farmers borrow boars to avoid maintenance costs. Mating is then either paid in cash or by

giving a female piglet at weaning. Some farmers do not charge friends or relatives for mating with their boar.

Table 5 Reform of sows (number of parturition) and boars (number of years use) (% of households) (n=40 per site). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
Sows (parturition)(χ^2, P<0.001)[1]								
1 to 2	8,6	24,3	12,9	18,2	30	50	7,4	23,1
3	68,6	59,5	54,8	51,5	57,5	47,5	44,4	56,4
4	14,3	10,8	9,7	18,2	10	0	22,2	15,4
5	8,6	5,4	22,6	12,1	2,5	2,5	25,9	5,1
Boars (years)(χ^2, P<0.001)								
1	22.7	70.8	46.2	3,6	77,5	0	12,5	25,8
2	50.0	12.5	30.8	60,7	12,5	61,5	50,0	25,8
3	18.2	12.5	7.7	25,0	2,5	38,5	25,0	29,0
≥4	9.1	4.2	15.4	10,7	7,5	0,0	12,5	19,4

3.6. Health issues

The main disease constraints mentioned by the farmers, were African swine fever (ASF) (95 %), swine erysipelas, diarrhoea, trypanosomiasis, worm infections (Table 6) and to a lower extent various diseases such as mange, enteritis, cysticercosis, colibacillosis, respiratory disease, coccidiosis, paralysis, pneumonia and smallpox.

Table 6 Main diseases reported by pig smallholders in the Democratic Republic of Congo (% of farmer) (n=40 per site and per disease). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo				
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan	χ^2, P[1]
ASF	71	100	100	95	92	100	100	100	<0.001
Swine erysipelas	55	65	73	18	78	95	91	8	<0.001
Trypanosomiasis	45	23	42	18	41	31	52	0	<0.001
Diarrhoea	58	23	37	39	54	49	12	3	<0.001
Worm infection	18	10	15	13	35	33	9	0	<0.001

Globally, ASF was the most feared by almost 100% of the pig smallholders. The noted diseases were identified by the farmer or by a veterinarian according to the symptoms, seldom by sample analysis in a laboratory. The majority of farmers (74 %) never called a veterinarian and there was no site difference (P=0.099). Except for the Mont-Ngafula site, most of those who did not call a veterinarian, practice self-medicine while the remaining did not take any action because of a lack of financial resources. The use of vaccine depended on the investigated site (Table 7). Some farmers declared to have vaccinated their herd against swine erysipelas (43%). Moreover, some farmers declared that they had vaccinated their animals against ASF (53%) and trypanosomiasis (45 %) while to our knowledge no vaccine exists against any of these two diseases.

Table 7 Type of vaccine administered to pigs in the Democratic Republic of Congo (% of response). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
(χ^2, P<0.001)[1]								
Trypanosomiasis	64	17	60	16	7	21	23	14
Swine erysipelas	8	34	31	24	7	29	38	43
ASF	20	48	6	16	86	46	39	14
Other	8	0	2	44	0	4	0	29

3.7. Housing system

Permanent housing was practiced among all sites (P=0.31) with very little free-roaming pigs that were found in Kasangulu and Kisantu (Table 8). Four types of materials used to build walls were identified: (i) concrete, (ii) burnt-brick, (iii) mud-brick and (iv) wood and showed significant differences between sites (P<0.001). Durable materials (cement bricks and corrugated galvanized iron) were used in almost all urban sites (Kinshasa) while Mud bricks or wood and straw were used in rural sites (Bas-Congo) (Table 8). All the farmers used almost the same housing management and had separated fattening and maternity pens.

Table 8 Pigsties building material and feeding equipment in the Democratic Republic of Congo (n=40 per site). [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
Housing (χ^2,P=0.31)[1]								
Permanent	100	100	100	100	100	100	97	95
Periodic	0	0	0	0	0	0	3	5
Building material (χ^2,P<0.001)								
Durable	8	90	80	85	38	67	7	15
Semi-durable	3	5	2	10	56	5	93	85
Wood and straw	90	5	17	5	5	29	0	0
Feeding equipment (χ^2,P <0.001)								
Feeders	69	33	41	61	77	44	17	34
Drinkers	90	95	95	90	80	68	100	94

There were site differences in presence of feeders and drinkers in pigsties. Feeders were present in only 47 % of the farms and drinkers in 89 %. Materials used as feeders/drinkers were plastic basin, open plastic containers placed in an open wooden box or in large aluminum pot. Pigs'drinking water depends on location and came either from tap water, wells, rivers or from springs (Table 9).

Table 9 Origin of drinking water in 319 Congolese pig production systems. [1]P: Chi-square tests, probability between sites

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
Origin of water (χ^2,P <0.001)[1]								
Tap water	10	24	0	12	82	12	9	89
Rivers	51	5	16	26	0	73	31	5
Wells	18	63	76	26	18	2	3	5
Springs	21	8	8	37	0	12	57	0

3.10. Feeding system

Correspondence analysis revealed that the various ingredients used in pig feed depended on location (Figure 1). Dimension 1 contrasted agro-industrial by-products with cassava. Dimension 2 did not provide enough information because the feed ingredients they tend to contrast are poorly used. The approximation of Boma to urban sites was due the use of palm kernel cakes and brewers grains. Kimbanseke was isolated from the other urban sites due to the high frequency of use of rice and corn bran.

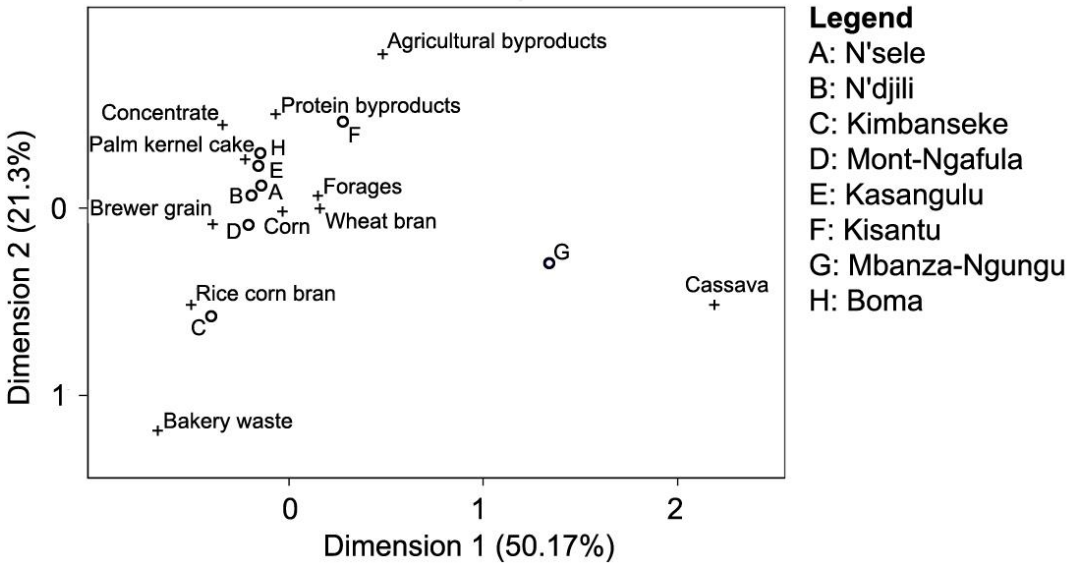

Fig 1 Reconciliation between sites in terms of feed ingredients in Congolese pig production systems.

Ingredients used in pig diets varied with the location (Table 10) and only 4% of farmers used commercial concentrate. Forage plants were fed to the pigs by almost all the farmers among all sites, with exception of Mont-Ngafula and Kasangulu where only up to 2/3 of the farmers used forages to fed the animals (P = 0.035).

Table 10 Percentage of response for the use of feed ingredients by pig producing farmers in Congo. [1]P: Chi-square tests, probability between sites.[2]Protein by-products include fish meal and fresh gills, caterpillar meal, and okara. [3] Agricultural by-product include corn bran, cassava and sweet potato peelings and flour by-products, palm kernels, and wheat bran

	Kinshasa				Bas-Congo				
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan	χ^2, P[1]
Wheat bran	100	87	85	93	9	88	82	92	<0.001
Palm kernel cake	95	87	75	64	94	10	91	79	<0.001
Brewers grain	63	82	78	66	57	5	42	5	<0.001
Corn	54	85	40	27	3	29	36	26	<0.001
Rice and corn bran	29	18	65	39	0	0	21	5	<0.001
Cassava	2	0	0	2	3	88	3	13	<0.001
Bakery waste	2	15	65	16	0	0	0	0	<0.001
Protein by-products[2]	12	26	0	7	3	2	12	16	<0.001
Agricultural by-products[3]	2	5	0	9	0	5	0	37	<0.001
Commercial feed	7	0	0	7	0	0	21	0	<0.001
Forage plants	95	95	95	67,5	100	100	62,5	97,5	0.035

Forty-three plant species were mentioned during the survey among which 33 could be formally identified. The most cited were vegetable crop by-products as well as *Manihot esculenta* leaves, *Ipomoea batatas* leaves, *Eichornia crassipes*, *Psophocarpus scandens*, *Pueraria phaseoloides*, *Boerhavia diffusa*, *Musa* spp. leaves and *Carica papaya* leaves (Table 11). The used plant species varied among the study sites.

Table 11 Plant species and plant parts that were used by 319 Congolese farmers to fed pigs (% of response). [1]unfit for human consumption or unsold; [2]P: Chi-square tests, probability between sites for the same plant species

		Kinshasa				Bas-Congo				χ^2, P^2
	Plant part	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan	
Manihot esculenta	Leaves	13	5	8	10	75	90	41	26	<0.001
Ipomoea batatas	Aerial parts	13	30	18	23	15	85	27	16	<0.001
Vegetables[1]	Leaves and roots	5	57	47	20	13	10	41	95	<0.001
Eichornia crassipes	Whole plant	56	38	53	13	10	0	5	3	<0.001
Psophocarpus scandens	Aerial parts	36	32	18	20	55	2	0	3	<0.001
Pueraria phaseoloides	Aerial parts	0	0	3	20	3	78	5	21	<0.001
Boerhavia diffusa	Aerial parts	8	3	11	7	68	0	9	3	<0.001
Musa spp	Leaves	3	11	5	10	35	0	9	13	<0.001
Carica papaya	Leaves and fruits	15	8	8	13	20	0	5	13	<0.001

3.9. Marketing

There was no difference in origin of starting animal stocks between sites. In general, animals were purchased in the neighbourhood from other smallholders (97%) without breeding selection, seldom in industrial pig farms (2.5%) or religious congregations (0.5%). The two latter generally raise improved European pig breeds. Finished pigs were sold alive or slaughtered directly for the end consumers. The average selling price depended on site ($P<0.0001$) and ranged from 2.00±0.2 USD in Boma to 4.12±1.0 USD in Kasangulu per kg live weight and from 3.00±0.1 USD/kg in Boma to 4.96±0.8 USD/kg in Mont-Ngafula for pork (Table 12).

Table 12 Average selling price of live animal and pork on eight study sites in the Democratic Republic of Congo ($ USD/kg). * In a row, means followed by a different letter differ at a significance level of 0.05.

	Kinshasa				Bas-Congo			
	N'sele	N'djili	Kimba	Mont	Boma	Mbanza	Kasang	Kisan
Live animal	3.24^{b} ±1.1	3.28^{b} ±0.9	3.00^{b} ±0.7	3.91±1.1	2.00^{a}±0.2	2.17^{a} ±0.9	4.12±1.0	2.18^{a} ±1.1
Pork	3.75^{bc} ±0.8	4.28^{cd} ±0.8	4.35^{bcd} ±1.1	4.96^{d} ±0.8	3.00^{a} ±0.1	3.39^{ab} ±0.6	4.50^{d} ±1.1	3.39^{ab} ±0.9

Pigs were slaughtered, sold and consumed mainly for great feasts such as New Year, Christmas or Wedding parties (45%) or when an unexpected need of money occured (20 %). Some breeders (20%) consumed only the fifth quarter (bowels, liver, kidney, lung, stomach sometimes the head) of the slaughtered animals while the best pieces were sold for cash income.

4. Discussion

The purpose of this study was to understand whether and how smallholder pig production systems varied in management and feeding strategies in periurban and rural areas in the Western provinces of the Democratic Republic of Congo. Although the four periurban sites were quite

286 similar across all investigated variables, no specific variable could be found that discriminated the
287 four periurban sites from the four urban sites due to strong differences within the four rural
288 locations.
289 Regardless of the location, all family members played a role in the pig raising activity. Nonetheless,
290 women were usually kept away from pig daily activities which differed from results of surveys
291 conducted in Kenya (Kagira *et al.*, 2010), where women were shown to play a bigger part in pig
292 raising activities. The low participation of women however agreed with data collected in Botswana
293 (Nsoso *et al.*, 2006). The implication of the family workforce into pig breeding can contribute
294 positively to a reduction in production cost and improve livelihood and hence shows the importance
295 of this activity as a source of family income
296 The average herd size was higher (18 individuals) than what has been reported in Northeast India
297 (Kumaresan et al., 2009a) and in most developing countries, e.g. herd size of six indivuals in
298 Vietnam (Lemke et al., 2007), three individuals in Nigeria (Ajala *et al.*, 2007) or approximately 4
299 individuals per herd in western Kenya (Kagira *et al.*, 2010). This herd size can be considered as
300 indication of market orientation. Sites in the outskirts of the metropolis of Kinshasa had a herd of
301 swine of greater size than those in rural areas. Kasangulu is in Bas-Congo closest to Kinshasa.
302 This position justified the large size of livestock and high price of livestock products. The large
303 average herd size in Mbanza-Ngungu is probably related to the fact that it is located far from
304 fishing sites (as opposed to Boma) and the low cost imports of Kinshasa which forces the
305 population to raise their own pigs to be supplied with animal protein sources. Pig production
306 received less attention in Boma because of supply of Congo River fish. The productive outputs in
307 Kasangulu are higher than in most of the other sites, especially regarding weaning weight and the
308 number of born and weaned piglets per litter (Table 3). Kansangulu is located quite close to
309 Kinshasa (approx. 50 km) which with its 8 million inhabitants represents a huge market. Farms in
310 Kansangulu still benefit from low costs of transportation for both pig products and feed and agro-
311 industrial by-products for feeding pigs. Farmers are more prone to increase productivity by, among
312 others, feeding more concentrate and agro-industrial by products (Table 8) and hire skilled workers
313 (Table 1). Moreover, farmers in Kansangulu do not suffer from environmental constraints as the
314 farms located in more densely populated periurban municipalities. Herd size is also likely to be

315 related to availability of land (Katongole *et al*., 2012). This explains why bigger herds were
316 observed in the rural location close to Kinshasa (Kasangulu) than in the periurban areas of
317 Kinshasa. In the studied system, the majority of the farmers were breeding sows for the production
318 of piglets. They fatten their offspring and sometimes additional piglets are bought from other pig
319 smallholders. A weakness of this system is that a large number of farmers do not have their own
320 boars which may lead to inbreeding (Kagira *et al.*, 2010; Lemke *et al.*, 2007). Mating fees
321 practices, charging or by submitting a female piglet at weaning, is similar to what has been
322 observed in other smallholder systems (Lañada *et al.*, 2005; Mutua *et al.*, 2011).
323 Weaning occured late compared to what was observed with native pigs in Kenya (Mutua *et al.*,
324 2011) and Creole piglets in Guadeloupe (Gourdine *et al.*, 2006) but coincided with observations
325 from free-range systems in western Kenya (Kagira *et al.*, 2010). The weaning age was more
326 determined by the health of the piglets and the sow as well as the quality and availability of feed
327 rather than by managerial decision based on age or weight of the litter. Late weaning age was
328 probably related to insufficient and unbalanced diet and resulted in a reduction in the numbers of
329 litters per years. The distribution of unbalanced diets to pigs is known for causing a decrease in
330 animal performances (Kumaresan et al., 2009b). Because of these probably unbalanced diets
331 weaning weight was low, although piglets were weaned quite late and some of the surveyed pigs
332 were hybrids of improved breeds which performances were expected to be better than those of
333 local pigs.
334 The average number of pigs born alive was consistent with what was observed in other developing
335 countries for native breeds (Mutua *et al.*, 2011; Ocampo *et al.*, 2005) but lower than that for
336 improved breeds raised on well balanced diets in open-air stables in the tropics (Suriyasomboon *et*
337 *al.*, 2006; Tantasuparuk *et al.*, 2000). The small litter size can be attributed to poor diets and
338 inbreeding because inbreeding negatively affects litter size (Toro et al., 1988), birth weight (Brandt
339 et al., 2002) daily gain and final weight (Fernandez et al., 2002). Inbreeding also stems from the
340 fact that pig farmers started generally this activity with poor breeders purchased from neighbors
341 without breeding selection. In addition, farmers reformed sows early (after three parities) which
342 reduced the possibility of having large litter sizes since it is known that litter size is usually smaller

343 in the first parity and rises to a maximum between the third and fifth litter (Koketsu & Dial, 1998;
344 Tummaruk *et al.*, 2001).
345 All the diseases mentioned by the farmers in this survey were also reported in African free-range
346 pig systems (Ajala *et al.*, 2007; Kagira *et al.*, 2010). The greatest health risks associated with pig
347 farming in this region are ASF and cysticercosis (Praet *et al.*, 2010), although in our study,
348 cysticercosis was neither mentioned by the Congolese pig farmers nor by the area's veterinaries,
349 probably because it has no overt disease-specific manifestations (Praet *et al.*, 2010) and its
350 prevalence is higher in free-roaming and scavenging pig systems. ASF causes major economic
351 losses, threatens food security and limits pig production in affected areas (Costard *et al.*, 2009;
352 Fasina *et al.*, 2011). It spreads quickly among smallholders for several reasons: transfer of animals
353 from one farm to another without quarantine, moving boars for mating, buying feed to retailers who
354 own livestock themselves, and closeness between farms. The current study also put in evidence
355 that farmers are often misinformed or misadvised over the effectiveness of some veterinary
356 treatments and vaccines.
357 Pig trypanosomiasis as zoonosis deserves a special attention to avoid circulation of this disease
358 between humans, pigs and tsetse flies. *Trypanosoma brucei gambiense* was identified in tsetse fly
359 with a blood meal from a pig in Kinshasa. In addition, pigsties occurred to be the most favorable
360 biotope for tsetse flies (Simo *et al.*, 2006a and 2006b). Poor hygienic conditions make pigs less
361 productive and more susceptible to diseases (Renaudeau, 2009). Absence of feeders and
362 subsequent distribution of feeds on the floor lead likely to contaminations and increase the
363 incidence of worm infection.
364 The results of the current study showed that the animals were mainly given agro-industrials and
365 agricultural by-products and plants even when other feed ingredients more energetic such as corn,
366 cassava and potato tubers were available. Also, ingredients used in pig diets varied with location
367 (Table 10) depending on local availabilities and what potential customers were willing to pay.
368 Unlike other sites, pig breeders of the rural Kasangulu area seemed to use the same pig feeds as
369 the farmer in urban sites. Brewer's grains were used near breweries which were located in
370 Kinshasa and Boma and were used thus by more pig farmers in Kinshasa than by those farmers in
371 Kasangulu and Boma and rarely by farmers in Kisantu and Mbanza-Ngungu. For the same

372 reasons, also forage plants were less used in Kasangulu than in other sites. Palm cakes were less
373 used in Mbanza-Ngungu probably due to the high transport cost because this site is located at 150
374 km from Kinshasa and 370 km from Boma were oil cakes were pressed. Cassava is the main
375 source of energy used in Mbanza Ngungu probably because of its affordability due to its
376 availability. Most of these feed ingredients are low in protein. The use of corn to feed pigs was
377 considered as a waste of money by rural pig farmers as they considered that they earn more
378 money by selling the grain directly than using it to feed their pigs. Instead of using corn, cassava or
379 potato tubers, they used fiber-rich ingredients such as wheat bran, palm kernel cake, brewers'
380 grains or plants to feed the animals. They used those ingredients regardless of the nutrients that
381 they provide. The majority of farmers producing pig and crops were even not able to cover
382 household self-sufficiency with their crop production. Their exceeding crop products were rather a
383 source of income than used as feed ingredients. They preferred to use plants as feed ingredients
384 instead. This choice not to divert food resources such as corn that could be eaten by the family or
385 sold on the market to feed pigs was a consequence of a least developed country production
386 environment where humans and animals are in direct competition for grains. Cooked cassava
387 leaves were more frequently used in rural sites than Kinshasa because in the capital city of DRC,
388 there is a high demand for cassava leaves to prepare the traditional dish called *pondu*, and hence
389 only few leaves were available for pigs. Sweet potato leaves were more used in Mbanza Ngungu
390 where there is a large production of potato tubers. *Eichornia crassipes* is fed to pigs in Kinshasa
391 close to the places where it can be found floating on rivers and ponds. *Psophocarpus scandens* a
392 protein-rich legume (Bindelle et al., 2009) is offered to pigs in Kinshasa and in Boma only. The
393 system of raising pigs on locally available resources has been already reported in Northeast India
394 (Kumaresan *et al.*, 2009a) and in North Vietnam (Lemke *et al.*, 2006). However, the choice of plant
395 as feed for pigs was not motivated by their palatability or nutritional value, but rather by their
396 availability. The lack of information on the chemical composition and the role of each nutrient on
397 pig growth is an obstacle to formulate balanced diet for weaned piglets, and gestating and lactating
398 sows which have highest nutrient requirements. Determining the chemical composition and
399 nutritive value would allow farmers to select plants that are nutrient-dense, palatable, digestible
400 and capable of covering the requirements of the animals to obtain a good growth from their pigs.

A large proportion of the Congolese smallholder pig production were market directed, as already mentioned for other African areas (Ajala *et al.*, 2007; Kagira *et al.*, 2010), aiming, first, to provide cash to the family. Supporting the family's consumption of animal products came only in the second position. This lies in contrast with Asian areas where pigs are less market oriented but fulfil functions related to savings and household consumption (Kumaresan *et al.*, 2009a; Lemke *et al.*, 2006).

Although no general differences were observed between the four rural and the four periurban sites, it can be concluded that pig husbandry depends on the local environment as strong differences were observed between rural sites, particularly in terms of workforces, herd structure and characteristics, production parameters, pig building materials, selling price and especially in feed resources. Farmers used several alternative feed ingredients to fed pigs such as agro-industrial by-products as long as the industry was not located too far away and the cost of transportation could be coped with thanks to high pig selling prices. Any further actions to improve pig production in Congolese pig production systems should consider differences in system's resources and constraints. Such actions should be articulated around three major pillars that were identified in this survey as the most critical: (1) a reduction in inbreeding, (2) an improvement in biosafety to reduce the incidence of African swine fever and the spread of other diseases, and (3) an improvement in feeding practices. The first two aims can be reached by training pig producing farmers, while an improvement in pig diets quality requires further research on the nutritional value of different feed resources and plant materials locally available, especially those rich in protein.

Acknowledgements

The authors gratefully thank Wallonie-Bruxelles International (WBI, Brussels) and the Direction générale de l'Agriculture des Ressources naturelles et de l'Environnement (DGA-RNE, Namur, Belgium) for support (CAVTK project grant).

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