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Success drivers of pig artificial insemination based on imported fresh semen

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This study was conducted to assess the factors that affect pig litter size, proportion of live pigs at birth, number of inseminations per conception, and efficiency of artificial insemination. The main factors assessed were sow breed (n = 2), sire breed (n = 3), sow parity (n = 7) and insemination method (n = 2). The sow breeds used were Landrace, LL (n = 27) and Landrace × Pietran crossbreds, LP (n = 37); boar breeds used were Landrace (LL), Pietran (PP) and Landrace × Pietran crossbreds (LP). Sows were randomly inseminated either by boar or artificially, with semen freshly imported from Belgium to Rwanda. Landrace (LL) sows had significantly smaller (P<0.05) litter sizes at birth (9.04±0.72) compared to LP sows (11.49±0.45). On the other hand, the litter size for LL (9.04±0.58) and LP (11.49±0.67) sires did not differ, while PP sires had the highest (P<0.05) litter size (13.37±1.43). Interestingly, the method of insemination, whether use of a boar or artificially did not (P>0.05) affect the number of inseminations per conception, litter size, and proportion of piglets born live. Sow parity was found to have a linear relationship with a mean litter size at birth of 6.9±0.43 piglets for primiparous sows and 15.2±1.12 piglets for a sow of parity 7. However, the number of piglets born dead increased with parity, peaking at 3.0±0.66 (parity 7), while it was only 0.2±0.2 for parity 1. Therefore, the LP crossbred sows and Pietran sires are recommended. Artificial insemination should be promoted since it performed as well as natural insemination but provides other advantages such as African swine fever and inbreeding prevention, and avoids boar management costs.

Key words: Breeding, genetic merit, performance, Pietran, pigs.

INTRODUCTION

The global pig population in 2017 was estimated at 784.83 million head (National Hog Farmer, 2017), with China leading in pig population at 435.04 million head, the top pork-producing country at 51.85 million tons (47.9% of world total), top pork-importers (40% of world total), and also the leading per capita pork consumer at 40.9 kg (National Hog Farmer, 2017; Statista, 2018). In Africa Uganda leads the per capita pork consumption at a meagre 3.5 kg (Birungi et al., 2015; Kugonza et al., 2015), and hence a lot still has to be done on the

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continent. Pig production has been growing on the African continent, and particularly in Rwanda; the growth has been consistent especially during the post-conflict years. The most recent census put the national pig herd at 706,000 animals (NISR, 2011), having risen by 35.4% during the period 2005 to 2010. The massive shifts are being driven by increased demand for pork and pork products such as sausages, bacon and special cuts. Along with other livestock species, notably cattle, goats and sheep; pigs contribute 12% of the Rwandan GDP, and a significant 32% to the agricultural GDP (NISR, 2017). Pig farming in peri-urban areas is highly competitive when compared to goat and cattle farming (Nabikyu and Kugonza, 2016). This is attributed to pigs requiring less land per livestock unit for acceptable levels of production. Farmers in peri-urban areas in much of East Africa also have access to agro-industrial by-products such as wheat pollards, brewers waste, molasses, and brans of maize, rice and wheat (Mwesigwa et al., 2013; Kugonza et al., 2015). These feedstuffs form the basal diet of pigs under commercial production. A major drawback to improving productivity is the breeding management, especially regarding unavailability and limitations in propagation of superior pig genetic material.

The use of artificial insemination (AI) technique for pigs and non-bovine livestock is very limited in Rwanda. The major driver of AI use is the need to disseminate superior genes within a given population at a reasonable cost. The greatest advantage of promoting AI use is that it will make possible, the widespread use of outstanding breeding sires and dissemination of valuable genetics to both big and small farms. This will lead to faster genetic improvement of the national pig herd. Pig AI technology has been in use in Northern Rwanda at a private farm but is yet to be tried out at community level, where breeding boars are still communally used through natural service. Small/medium scale farmers who do not own boars on their farms rely on a neighbour’s boar to breed their sows. This has also been reported in neighbouring Uganda where over 52% of smallholder pig farmers do not own a breeding boar (Bamundaga et al., 2018). However, this practice of communal boars promotes the spread of diseases especially African swine fever and various reproductive diseases because of the movement and contact between animals. Also, the sharing of the boar by many farmers leads to its overuse which might explain the occurrence of small litter sizes at subsequent births. This ultimately leads to a low number of pigs per sow per year and economic loss.

AI of the pig involves collection of semen from a boar and then introducing it into a sow or gilt later on by means of a catheter (Ikani and Dafwang, 1999; Bamundaga et al., 2018). It differs from natural service which involves a boar mounting the sow and introducing his semen by copulation. Sperm, the main ingredient in semen was first seen by Leeuwenhoek and Hamm in 1678 (Foote, 2002). Then, the first successful insemination was performed in dog by Spallanzani in 1784 and over a century later, in 1897, AI in livestock specifically rabbits and horses was then reported (Foote, 2002). Pig AI was first performed by Ivanoff in Russia almost a century ago (Ombelet and Van Robays, 2015) however, its wide commercial application in pig production is more recent. It is just over two decades ago when insemination protocols for pig AI were standardized (Gadea, 2003), and related work continues. A contemporary study (Bamundaga et al., 2018) has recently established that single and double AI protocols lead to non-varying conception rates (94.4 versus 89.6%), and litter sizes (8.16±0.34 versus 9.00±0.39 piglets).

Recent estimates put pig AI at nineteen million inseminations worldwide per year and of these, almost all (99%) are done using boar semen preserved at temperatures of 15 to 20°C (Johnson et al., 2000). AI in pigs: (i) Allows for the wider use and distribution of boars of high genetic merit; (ii) Allows up to 25 sows to be served with semen from one boar ejaculate, each dose given to a sow containing 2 to 3 billion spermatozoa in 80 to 100 ml (Maes et al., 2010); (iii) Prevents the transmission of diseases from farm to farm by the movement of sows to and from the boar as well as the sale of diseased boars; (iv) Helps to overcome the challenge of differences in size of males and females, especially the limited use of heavy boars which may be of high genetic caliber; (v) Eliminates the need to purchase, house and feed boars especially on small scale agriculture; (vi) Reduces the farmers risk of handling boars for use in natural service (Ikani and Dafwang, 1999).

Currently, the pig breeds reared in Rwanda include Large White (on 22.9% of pig farms), Landrace (37.7%), Pietrain (7.3%), Duroc (1.6%), Local (2.3%) and non-descript crossbred (28.1%) pigs (Mbuza et al., 2016). The local pigs are black in colour or black in mixture with white. The productivity of the local pigs is still very low, characterised by low birth weight and slow growth rate. The average age at first farrowing of sows is between 18 and 24 months, while the number of piglets born from the black pigs range from 8 to 10 piglets, and a mature weight of 120 kg is attained in pigs aged 18 months (RARDA, 2010). For the Large White breed, the average weight of 70 kg is attained at 5 months, while first farrowing occurs at 12 months, with a litter size of 10 to 12 piglets. Growth performance of the Landrace breed is generally better than the Large White although performance data is not readily available (RARDA, 2010). Pietrain pigs on the other hand generally have lower growth rates but produce predominantly lean carcasses when the effect of feed is accounted for. This study was therefore conceived to study the major factors that influence the success of an artificial insemination programme that uses imported fresh boar semen.

MATERIALS AND METHODS

Ethical approval

This research followed ethical standards and complied with regulations of the Rwanda National Council for Science and Technology.

Study location

The study was conducted at *Centre de Perfectionnement agricole et elevage de Kisaro* (1°37'41.99''S; 30°01'39.11''E), a private farm located at Kisaro sector, Rulindo district in the Northern province of Rwanda. The site is at around one and half hours' drive from Kigali City.

Experimental animals

Sixty-four sows of Landrace breed (n = 27) and Landrace × Pietrain crossbreed (n = 37) were used in this study. The sows were of parities ranging from one to seven. Semen or boars used were of Landrace breed (n = 28), Pietrain breed (n = 15) and Landrace × Pietrain crossbreeds (n = 21). Forty of the total experimental sows were bred using artificial insemination, while twenty four were bred using natural mating with the boar. The experiment was conducted over eight month duration.

Source of semen for artificial insemination

Fresh semen was imported from Hypor (a Hendrix genetic company), a breeding company based in Belgium (HYPor Belgium V, Leie Rechteroever19870, Olsene Belgique, T 014 63 53 47, F014 63 54 79, (www.hyvarselect.be). Semen collection was performed the day prior to shipment to Rwanda. Semen was collected from several boars, pooled and then extended using standard protocols before being shipped.

Housing

All pigs at the farm were kept indoors, adults in individual pens, while weaners and growers were reared in groups of up to ten. Individual pens were made of a concrete floor, with walls of brick measuring up to 1.5 m in height. The average floor space area per adult pig was up to six square metres. Farrowing pens measured 2.5 m by 2.5 m, boar pens measured 2.5 m by 1.25 m while grower pigs were kept in pens measuring 2.5 m by 1.25 m. Pig house roofs were made of corrugated iron sheets.

Feeding

The main diet of the pigs was a composite ration made of maize bran, wheat bran, bone meal, soybean meal, fish meal, vitamin mineral premix and salt. The wheat and maize used in feed formulation was largely produced on the farm. The pigs were fed twice a day, at 09:00 to 10:00 h, and at 15:00 to 16:00 h. On average, each mature pig was given 2.5 kg of the composite ration per day, with bigger sows getting proportionately higher amounts. Water was provided *ad libitum*.

Piglets were farrowed in specialized farrowing pens (2.5 m x 2.5 m) and received an injection of iron on the 3rd day of their lives. Piglets stayed with their mother from birth until weaning at two months, though they had access to creep feed placed in a specialized creep area, accessible only to piglets. Castration of male piglets was done within one to two and a half months of age. At weaning sows were removed from the pens and the weaned piglets were allowed to stay in the pens for extra one week. Afterwards, the weaners were segregated by sex and relocated to grower pens (2.5 m x 1.25 m) in groups of up to ten.

Breeding and health management

Sows naturally came on heat 3 to 7 days after weaning their litters, and had never been induced using hormonal treatment, but were regular breeders. Gilts were bred on their second heat, at the age of seven months. The sows were allocated individual pens next to adult boars to enable estrus detection. In addition, the back pressure test for standing heat reflex was performed and those that responded were considered to be in estrus. The sows were either taken to the boar for supervised service or were inseminated with imported extended fresh semen. Twenty four sows were served by boars twice using the AM-PM rule, so as to maximize on the conception rate. Each boar was allowed to serve a maximum of four sows a week to avoid them being overworked. Sows and gilts were served by boars in rotation to mimic AI where semen from several boars was pooled, in consideration of the desired breed. On the other hand, 40 sows were artificially inseminated twice, about 24 h between the inseminations using the AM-PM rule. Each dose inseminated by AI contained 2.5 billion spermatozoa in 80 ml. The intra-cervical method was used in all inseminations (Darwin, 2007), with extra care taken to minimize backflow. Conception was indicated by a non-return to heat after 18 to 22 days, the few gilts that did not conceive on first insemination were served again on the subsequent natural heat.

The pigs were washed every week using water and soap. There was no practice of spraying against ecto-parasites, instead, double-acting dewormer Ivermectin® was used for this purpose. The pigs were dewormed once every three months. Disease outbreaks were described by the farm management as being very rare on the farm.

Record keeping

Records on each piglet farrowed were kept on the farm. Records that were taken included farrowing date, sow breed, boar breed, parity of sow, litter size (number born alive and stillborn), method of insemination used, and live body weight (taken monthly). Dates of treatment in cases of disease, inseminations and routine animal management practices were recorded as well. The farrowing rate recorded was 86% and above.

Study design, data collection and data analysis

The study used a completely randomized design with sows that were recruited into the study randomly selected from the herd. Also, sows that were subjected to artificial insemination were randomly selected from the experimental group so as to avoid bias. Data were collected over an eight months period following specified/standard procedure, taking care to avoid stressing the animals, in consonance with the national provisions on animal welfare and ethics in handling experimental animals.

Data was checked for validity and was then entered into MS Excel spreadsheets. It was then subjected to analysis of variance using the generalized linear model procedure of Statistical Analysis Systems, version 9.2 (SAS, 2004). The fixed effects were sow breed, boar breed, sow parity, and insemination method. The model used for data analysis was:

$$Y_{ijklm} = S_i + B_j + P_k + I_l + SB_{ij} + SP_{ik} + BP_{jk} + PI_{kl} + e_{ijklm} \; N(0, \sigma^2_e) \qquad (i)$$

Table 1. Least square mean litter size, piglets born alive, stillborn piglets, inseminators per conception.

Factor	Level	Litter size	Piglets born alive	Stillborn piglets	Inseminations per conception
Sow breed	Landrace × Pietrain (n = 37)	11.49[a]	10.81[a]	0.67	1.02
	Landrace (n = 27)	9.04[b]	7.79[b]	1.25	1.11
Boar breed	Landrace × Pietrain (n = 21)	7.99[a]	7.51[a]	0.47	1.09
	Landrace (n = 28)	9.43[a]	8.29[a]	1.14	1.10
	Pietrain (n = 15)	13.37[b]	12.09[b]	1.27	1.01
Parity	1st (n = 21)	6.91[a]	6.76[a]	0.15[a]	1.06
	2nd (n = 15)	8.27[ab]	7.77[a]	0.50[a]	1.12
	3rd (n = 9)	9.96[ab]	8.75[ab]	1.21[ab]	0.98
	4th (n = 6)	9.28[ab]	8.28[a]	1.00[ab]	1.24
	5th (n = 5)	9.84[ab]	8.66[ab]	1.17[ab]	1.01
	6th (n = 4)	12.29[ab]	12.44[c]	-0.14[a]	1.02
	7th (n = 4)	15.29[c]	12.44[c]	2.85[b]	1.02
Insemination method	AI[§] (n = 40)	8.06	7.45	0.61	1.17
	NS[∫] (n = 24)	12.47	11.15	1.31	0.97
SEM		0.429	0.404	0.164	0.025
LSD		1.48	1.32	0.60	0.10

[§]AI = artificial insemination; [∫]NS = Natural service. [abc] = means with similar superscripts within column and factor are not different (P<0.05)

Where, Y_{ijklm} = observation of the variable for the a sow breed *i*, mated to boar breed *j*, for sow parity *k* and for insemination method *l*; μ = overall mean; S_i = effect of sow breed (i = 1,2); B_j = effect of boar breed (j = 1,2,3); P_k = effect of sow parity (k = 1,2,3,4,5,6,7); I_l = effect of sow insemination method (l = 1,2); SB_{ij} = effect of the interaction between sow and boar breed; SP_{ik} = effect of the interaction between sow breed and parity; BP_{jk} = effect of the interaction between boar breed and sow parity; PI_{kl}, = effect of the interaction between sow parity and insemination method; e_{ijklm} is the random effect on the trait, independently and identically distributed with mean = 0 and variance = σ_e^2.

Model (i) above was used in the preliminary analysis. Due to the finding that the sow and boar breed interaction effect SB_{ij}, the sow breed and parity interaction effect SP_{ik}, the boar breeds and sows parity interaction affect BP_{jk}, and the sow parity and insemination method interaction effect PI_{kl} did not significantly affect the variables, they were eliminated from the model, subsequently, the model finally used is shown as follow:

$$Y_{ijklm} = S_i + B_j + P_k + I_l + e_{ijklm} \quad N(0, \sigma^2_e) \qquad \text{(ii)}$$

Duncan's multiple range test was used to separate means.

RESULTS

The mean number of piglets born alive was 39% higher for crossbred sows compared to pure landrace sows (Table 1). However, the differences in number of piglets born live between boars of the two breed types were not significant; instead, it is the value for Pietrain boars that stood out; 53% piglets more than the other categories. Parity of the sow did not influence the number of piglets born alive, but it did significantly influence the total litter size. Litter size clearly increased with parity, rising consistently from 6.91 piglets for sows of first parity to 15.29 piglets for sows of parity 7, a 121% increment. The litter size as well as the number of piglets born alive did not differ between sows bred using artificial insemination and those that were bred using natural service.

The number of stillborn piglets was not affected by sow breed, boar breed, and insemination method; but was influenced significantly (P<0.05) by parity of the sow. In general, the number of stillborn piglets increased with parity (Figure 1), rising from 0.15 for primiparous (first parity) sows to 2.85 for 7th parity sows.

Considering the number of inseminations per conception, all the factors namely sow breed, boar breed, sow parity, and insemination method did not show significant differences (P>0.05).

DISCUSSION

This study focused on establishing the determinants of success in a pig artificial insemination programme using semen freshly imported from Europe to Central Africa. Sows inseminated artificially had a litter size of 8.06±0.42 piglets quite comparable to 9.06±0.4 piglets reported by Bamundaga et al. (2018) and 10.8±2.2 (Chanapiwat et al., 2014), and despite being in varying locations, the studies used landrace breed and its combinations with other breeds. Improvements in the management of

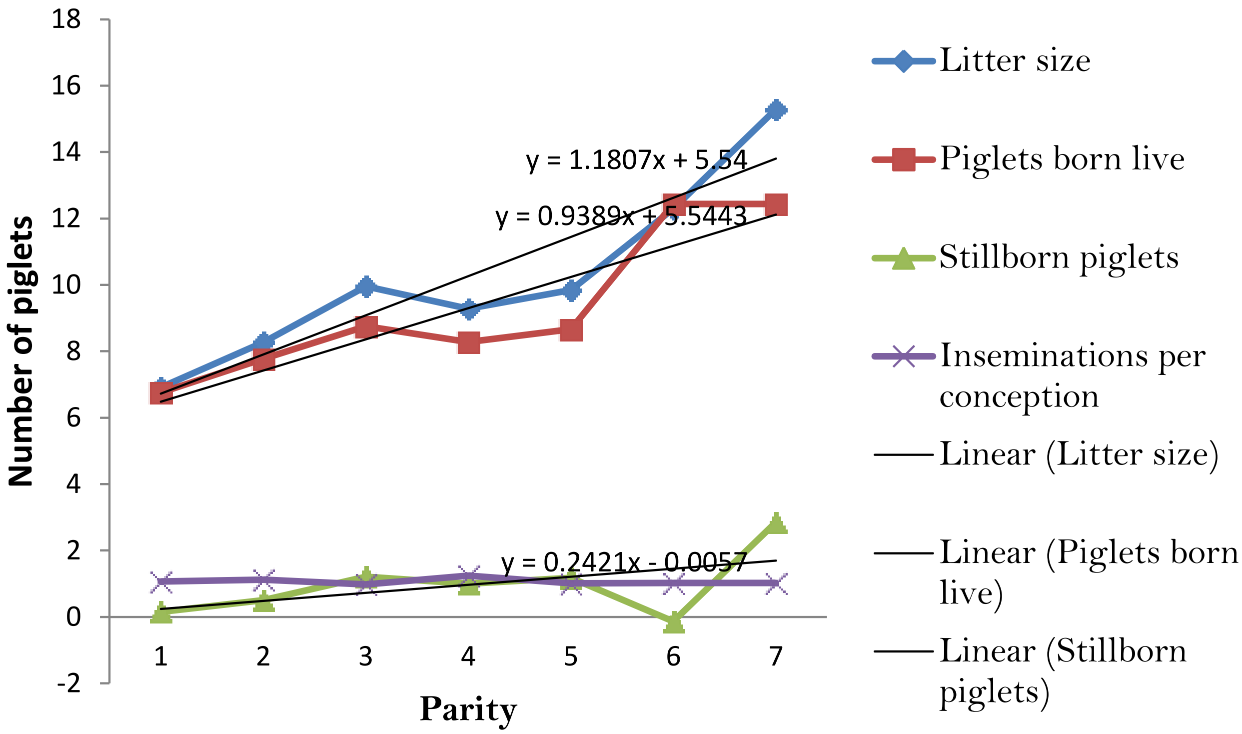

Figure 1. Effect of parity on litter size, piglets born alive and those born dead.

artificial insemination imply that the technology can continue to impact the pig industry. Despite Chanapiwat et al. (2014) reporting that the main limitation of the extended fresh semen is the short timing of semen storage, and the likelihood that semen cannot be transported for a long distance, results of this study that used semen transported from Northern Europe shows that this is not an issue. Instead, the chance of distributing a good genetic resource across countries and particularly, enabling locally raised sows to be bred with semen having the best estimated breeding values available in Europe is very real. Use of AI for breeding pigs has become instrumental for facilitating global improvements in fertility, genetics, labour, and herd health (Bortolozzo et al., 2015; Knox, 2016).

The differences in number of piglets born live between boars of the two breed types in this study were not significant (Table 1), instead, it is the value for Pietrain boars that stood out over the other categories. The establishment of AI centers for management of boars and production of semen has allowed for selection of boars for fertility and sperm production using *in vitro* and *in vivo* measures (Ringwelski et al., 2013; Knox, 2016).

Parity of the sow did not influence the number of piglets born alive (Table 1), but it did significantly influence the total litter size. Second parity sows have been reported to produce an average litter size of 8.36±0.28 when artificially inseminated, and 10.6±0.64 when naturally served by the boar (Ronald et al., 2013). While that study found the differences between the two methods were significant, this study found contrary results. Though the superiority of natural mating in both studies is vivid and indeed, this study found a higher litter size (12.47) than that of the Indian study, which was also done at a private farm. Low parity females especially pregnant gilts and primiparous sows have also been reported elsewhere to have lower reproductive performance than sows in parities between second and fifth parity (Koketsu et al., 2017). Sow fertility is also closely associated with varying doses of semen volume and spermatozoa count for AI (Apic et al., 2015).

While stillbirths were found in both artificially and naturally inseminated sows, other studies (Ronald et al., 2013) reported still births only in naturally inseminated sows. The variance between the two studies could be attributed to the parity factor, since the study had mixed parities, with older sows having high stillbirths and the values must have been responsible for swaying the overall mean.

Other contemporary studies also strongly support the position that number of piglets born and the number of live born piglets are highest in 2 to 3 parity sows and drop significantly in sows of more than five parities (Wegner et al., 2014). While the number of still born piglets was lowest in second parity sows (0.5), Wegner et al. (2014) found the lowest (0.8) in first parity sows, and the highest (1.44) in sows of more than five parities, slightly higher than 1.17 that was found in the current study.

Conception failures in pigs have been known to result from effects of the season, mode of insemination, age of the sow, and the number of times the female is inseminated, and the females' birth litter sex ratio (Drickamer et al., 1997; Wegner et al., 2014), this study differs having found that the mode of insemination and number of times the female is inseminated did not have significant effects.

Conclusion

Litter size of weaned sows bred by natural service or AI was the same. In addition AI has the significant advantage of enabling locally raised sows in Rwanda to be bred with semen having the best estimated breeding values available in Europe, from Belgium. AI relying on imported semen should be promoted especially for introduction of superior genetics for which grade boars may not be manageable in tropical Africa.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

REFERENCES

Apic J, Vakanjac S, Stancic I, Radovic I, Jotanovic S, Kanacki Z, Stankovic B (2015). Sow fertility after insemination with varying doses of volume and spermatozoa count. Turk. J. Vet. Anim. Sci. 39:709-713.

Bamundaga GK, Natumanya R, Kugonza DR, Owiny DO (2018). Reproductive performance of single and double artificial insemination protocol in swine. Bull. Anim. Health Prod. Afr. 66(1):143-157.

Birungi R, Ouma E, Brandes-van Dorresteijn D, Kawuma B, Smith J (2015). Pig marketing and institutional strengthening: Uganda smallholder pig value chain capacity development training manual. ILRI Manual 11. Nairobi, Kenya: ILRI.

Bortolozzo FP, Menegat MB, Mellagi APG, Bernardi ML, Wentz I (2015). New artificial insemination technologies for swine. Reprod. Domest. Anim. 50(2):80-84.

Chanapiwat P, Olanratmanee E, Kaeoket K, Tummaruk P (2014). Conception rate and litter size in multiparous sows after intrauterine insemination using frozen-thawed boar semen in a commercial swine herd in Thailand. J. Vet. Med. Sci. 76(10):1347-1351.

Darwin R (2007). Proper AI Techniques, Semen Handling, Swine Veterinary Center St. Peter, MN. available at: http://www.nationalhogfarmer.com/genetics-reproduction/artificial-insemination/proper-ai-techniques

Day C (2017). Global Mega Producer, Nat. Hog Farmer. 2017(6):22-24.

Drickamer LC, Arthur RD, Rosenthal TL (1997). Conception failure in swine: Importance of the sex ratio of a female's birth litter and tests of other factors. J. Anim. Sci. 75:2192-2196.

Foote RH (2002). The history of artificial insemination: Selected notes and notables. J. Anim. Sci. 80:E22-E32.

Gadea J (2003). Review: Semen extenders used in the artificial insemination of swine. Spanish J. Agric. Res. 1(2):17-27.

Ikani IE, Dafwang II (1999). Pig Production Technology for Piggery Farmers. National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria. Ext. Bull. 25(1):76

Johnson LA, Weitze KF, Fiser P, Maxwell WMC (2000). Storage of boar semen. Anim. Reprod. Sci. 62:143-172.

Koketsu Y, Tani S, Iida R (2017). Factors for improving reproductive performance of sows and herd productivity in commercial breeding herds. Porc. Health Manage. 3(1):1.

Knox RV (2016). Artificial insemination in pigs today. Theriogenol.. 85(1):83-93.

Kugonza DR, Lubandi C, Kirembe G, Taabu HL, Lusembo P (2015). Effect of genotype and post-weaning diet in enhancing pig production within Lake Victoria crescent in Uganda. Agric. Innov. Sustain. Dev. 4(3):296-304.

Maes D, Rijsselaere T, Vyt PH, Sokolowska A, Deley W, Van Soom A (2010). Comparison of five different methods to assess the concentration of boar semen. Flemish Vet. J. 79:42-48.

Mbuza F, Majyambere D, Ayabagabao JD, Dutuze MF (2016). Inventory of pig production systems in Rwanda. Int. J. Livest. Prod. 7(7):41-47.

Mwesigwa R, Mutetikka D, Kugonza DR (2013). Performance of growing pigs fed diets based on by-products of maize and wheat processing. Trop. Anim. Health Prod. 45(2):441-446.

Nabikyu JR, Kugonza DR (2016). Profitability analysis of selected piggery businesses in peri-urban communities of Kampala, Uganda. Livest. Res. Rural Dev. 28(5):1-10.

National Institute of Statistics of Rwanda (NISR) (2011). Statistical Yearbook, 2011 Edition.

National Institute of Statistics of Rwanda (NISR), (2017). GDP Annual Estimates 2017. National Institute of Statistics of Rwanda, Kigali. available at http://www.statistics.gov.rw

Ombelet W, Van Robays J (2015). Artificial insemination history: hurdles and milestones. Facts, views and vision in ObGyn 7(2):137-143.

Ouma E, Dione M, Lule P, Rosel K, Pezo D (2013). Characterization of smallholder pig production systems in Uganda: constraints and opportunities for engaging with market systems. Tunisia: International Conference of the African Association of Agricultural Economists.

Rwanda Animal Resources Development Authority (RARDA) (2010). Annual Report 2009-2010. Ministry of Agriculture and Animal Resources, Kigali, Rwanda.

Ringwelski JM, Beever JE, Knox RV (2013). Effect of interval between inseminators when using frozen-thawed boar semen on fertility and fetal paternity in mature gilts. Anim. Reprod. Sci. 137(3-4):197-204.

Ronald BSM, Jawahar TP, Gnanaraj PT, Sivakumar T (2013). Artificial insemination in swine in an organized farm – A pilot study. Vet. World, 6(9):651-654.

Statista (2018). The statistics portal: Statistics and studies from more than 22,500 sources. Available at www.statista.com

Wegner K, Lambertz C, Das G, Reiner G, Gauly M (2014). Climatic effects on sow fertility and piglet survival under influence of a moderate climate. Animal, 8(9):1526-1533.