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Factors influencing success of artificial insemination of pigs using extended fresh semen in rural smallholder pig farms of Rwanda

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The present study was conducted to analyse the factors influencing the success of artificial insemination (AI) in pigs using extended fresh semen in rural smallholder pig farms. One hundred female pigs from Rulindo and Gicumbi districts in Northern Region of Rwanda were artificially inseminated using locally collected and extended fresh semen. The pregnancy was confirmed by using both no returns to estrus and abdomen palpation at 21 and two and half months post insemination, respectively. The factors influencing the success of AI were analysed using one way analysis of variance (ANOVA) test. The results showed that the number of inseminations per conception (IC) and litter size were 1.89 ± 0.83 and 7.94 ± 2.24, respectively. The number of AI per conception was significantly influenced ($p < 0.05$) by intrinsic factors (age and parity of the female pig) and extrinsic factors (sex, age and education of household head, time of AI and distance between the farm and semen collection center). The litter size was significantly influenced ($p < 0.05$) by parity. From the results, we recommend establishing more semen production centers and providing more training on pig management and AI.

Key words: Inseminations per conception, litter size, swine, fresh semen, smallholder farms, natural oestrus.

INTRODUCTION

The world population continues to depend on pig meat as an important source of food and income. Pig meat contributes around 36% (118.7 million tonnes) to the world meat output comprising bovine, pig, poultry and ovine meat (FAO, 2018). Indeed, pig meat is the second, after poultry meat, among the most consumed types of meat worldwide (on average, 12.3 kg retail weight equivalent/capita/year) (OECD-FAO, 2018).

The demand for meat including pig meat, is expected to increase due to the growing world population. The

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projections have shown that the world population is expected to rise to 9.1 billion by 2050 (Godfray et al., 2010). Simultaneously, global pig meat consumption on a per capita basis remains stable: from the average of 12.3 to 12.2 kg retail weight equivalent/capita/year in 2015 to 2017 and 2027, respectively (OECD-FAO, 2018). Therefore, there is a need for increasing pig production in order to meet the growing demand in pig meat. The increase in pig production will be made possible through the use of improved technology in key areas such as genetics, nutrition, management, sanity and reproduction. Among these areas, genetics play a primordial role in improving pig meat production and artificial insemination (AI) technology is among the best alternatives for its improvement.

The use of AI in pig breeding presents great advantages, compared to natural mating, such as improving fertility, genetics, labour use efficiency and herd health which result in increased farm productivity and profitability (Knox, 2016). Artificial insemination enables to increase sire selection intensity by using the best sires available within individual breeds (Ronald et al., 2013). In fact, the use of AI greatly increases the selection differential, where the genetic potential of the best sires can be extensively transferred to a large number of pigs using diluted semen (Shimada et al., 2016). Artificial insemination technique solves problems of infections due to the contact between boar and female pigs during mating (Shimada et al., 2016). Some infections caused mainly by viruses and bacteria can result in problems associated with sperm damage, pregnancy failure, abortion, embryo loss and endometritis (Knox, 2016). Artificial insemination reduces the use of the same male by a group of farmers, particularly within a village, which can lead to inbreeding (Kumar et al., 2014). A standard farm boar to sow ratio is 1:20 using natural mating (Kyriazakis and Whittemore, 2006). Hence, AI can reduce the ratio to 1:150 (Roelofse, 2013). The reduced number of boars in a farm results in optimum use of the facilities and labour as well as reduction of feed supply and medicines; thus, monetary benefit (Ronald et al., 2013; Kadirvel et al., 2013).

The use of AI in pigs has presented an enormous progress, particularly in Europe and North America (Gerrits et al., 2005; Ronald et al., 2013). In some European countries, such as Belgium, Italy, the Netherlands, Norway and Spain, more than 80% of the female pigs are bred using AI. In North America (USA, Canada and Mexico) and Brazil, 75% of female pigs in large farm units are inseminated using AI (Feitsma, 2009; Roca et al., 2006). Moreover, the conception rates in AI and natural mating in pigs are the same (Kadirvel et al., 2013). Indeed, the fertility rates of 80 to 90%, using AI, are common in many pig farms (Roca et al., 2006) and artificial insemination can lead to better results in farrowing rate and litter size than natural mating (Visalvethaya et al., 2011; Am-in et al., 2010; Kadirvel et al., 2013).

Although AI in pigs has more advantages compared to natural mating, it can have some limitations. For example, AI in pigs can result in low number of piglets per farrowing compared to natural mating; and the limited storage period of fresh semen are the main problems to its expansion in the field all over the world (Shimada et al., 2016). Therefore, Maes et al. (2011) suggest that the success of AI in pigs is largely determined by the semen quality and the insemination procedure. Some of critical issues for AI procedure involve oestrus detection in the gilt/sow, timing of insemination, applying strict hygiene measures, semen age and age of boar (Maes et al., 2011; Feitsma, 2009). Practically, the success of AI can be gauged using specific parameters including fertility rate, number of inseminations per conception, farrowing rate, litter size, piglets born alive and stillborn piglets (Vargas et al., 2009; Niyiragira et al., 2018).

Despite its progress worldwide, the use of AI in pigs in Rwanda is still limited. Mbuza et al. (2016) reported that some pig farmers in Rwanda are not aware of the existence of AI in pigs. Moreover, Niyiragira et al. (2018) suggested that reproduction performances such as litter size of weaned sows bred by natural service and AI are similar; and some factors like sow breeds and parity can significantly influence the outcomes of AI namely litter size. However, the study was conducted in an organized farm, where a large number of factors, particularly socio-economic and management factors were controlled compared to smallholder pig farms in rural areas. Currently, the literature shows that there is no study related to factors influencing the success of AI in smallholder pig farms in rural areas of Rwanda. The present study aims to assess the factors influencing the success of AI using locally collected extended fresh semen in smallholder pig farms in rural areas of Rwanda.

MATERIALS AND METHODS

Study area

The study was conducted in Rulindo and Gicumbi districts in Northern Region of Rwanda during the rainy and dry seasons from January to September 2018. The districts are mostly characterized by hills interspersed by valleys and swamps that border rivers. In the two districts, agricultural sector provides the main jobs and source of revenues; where 76 and 77% of working population in Gicumbi and Rulindo districts, respectively, are involved in this sector. Around 14.7 and 14.9% of all households in Gicumbi and Rulindo districts, respectively, raise pigs. In this study, the semen were collected from *Centre de Perfectionnement et de Promotion Agricole de Kisaro (CPPA)* (1°37'41.99''S; 30°01'39.11''E), a private semen collection centre located in Kisaro Sector of Rulindo district. Figure 1 shows the location of Gicumbi and Rulindo districts and CPPA *de Kisaro.*

Semen collection, dilution and storage

The semen was collected by the trained technician of the semen collection centre of *Centre de Perfectionnement et de Promotion*

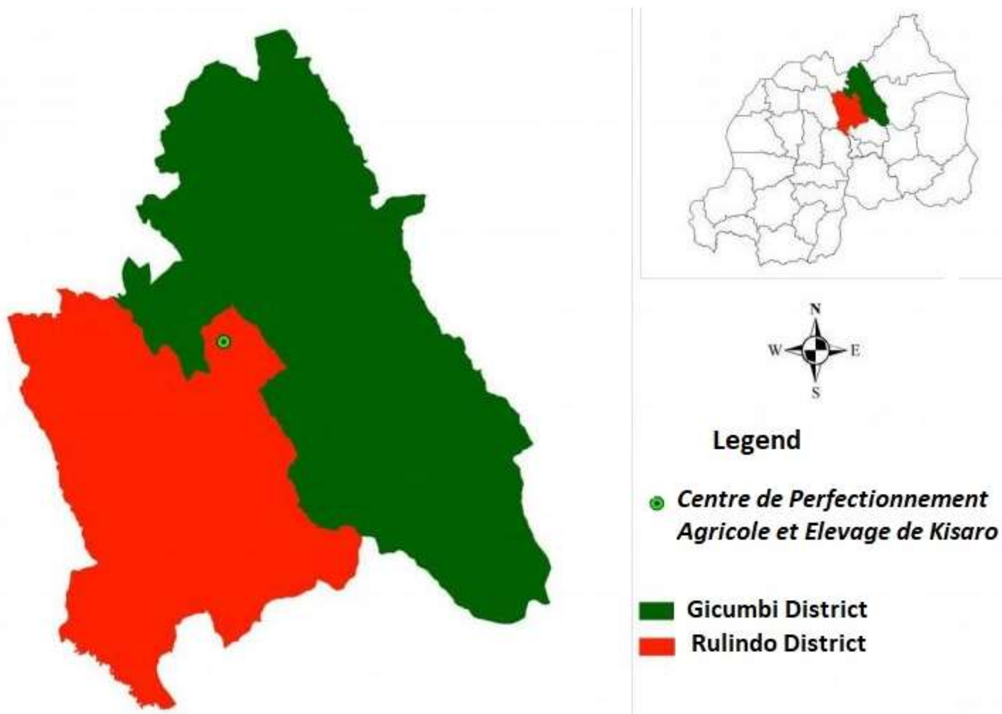

Figure 1. Location of Gicumbi and Rulindo districts and Centre de Perfectionnement et de Promotion Agricole de Kisaro (CPPA).

*Agricole de Kisaro (CPPA)*from the trained boars in a sterile beaker using a dummy sow. The motility and concentration of spermatozoa were assessed by using a microscope and spectrophotometer respectively. After estimating the concentration, the semen was immediately extended with the diluent to the final concentration of 3×10^9 spermatozoa per dose of 100 ml. Then, the extended semen was stored in squeeze bottles at a temperature between 15 and 20°C. The storage period of the extended semen varied depending on appearance of heat in female pigs to be artificially inseminated, but it did not exceed five days before their utilization.

Artificial insemination and pregnancy detection

A total of 100 female pigs from 100 farms were randomly selected on the basis of insemination service provider records. Practically, an exhaustive list of the artificially inseminated female pigs during the study period was provided and the sample pigs were randomly selected. Once a sow/gilt showed heat signs, the farmer informed the inseminator. Then the inseminator transported the extended semen to the farmer's place and inseminated the sow/gilt. A single AI per oestrus was performed for all sows/gilts using intra-cervical insemination (intra-CAI) procedure, as described by Kaysen (2013), 12 h after the pig had expressed oestrus signs. The pregnancy was confirmed by either no return to estrus after 21 days or abdomen palpation two and half months post AI. The inseminations were carried out by trained inseminators from CARITAS, a non-governmental organization that was providing artificial insemination service in the study area during the study period.

Data collection and analysis

The household and farm management data were collected using a structured questionnaire through interview with the farmers and personal observations. The farmers included 16 males and 84 females. The data related to AI were collected alongside the AI procedure using a predesigned form. The factors which were hypothesized to influence conception and litter size were categorized into those which are related to the female pig (intrinsic) and those which are not related to the female pig (extrinsic). The intrinsic factors were the age, parity and breed of female pig. The extrinsic factors were the age, the sex and experience in pig keeping of the household head, distance between AI centre and pig farm, time of AI, district and floor material of the pig house. A one way ANOVA test was used to analyse the difference between means of number of inseminations per conception and litter size among groups. Statistically significant difference between means was considered to exist if the *p*-value is less than 0.05. The data analysis was performed using SPSS-IBM 20 version software (IBM Corp. Released, 2011).

RESULTS AND DISCUSSION

Number of inseminations per conception

The overall number of artificial inseminations per conception (IC) was 1.89 ± 0.83. Moreover, the pigs that became pregnant after one, two, three and four AIs were 37, 77, 97 and 100% of the total sample, respectively (Figure 2). The average number of AIs per conception was higher than the ones reported in the literature. For example, Niyiragira et al. (2018) reported 1.17 AIs per conception in Rwanda while Ronald et al. (2013) reported 1.00 AI per conception in India. This superiority could be explained by the fact that those studies were conducted

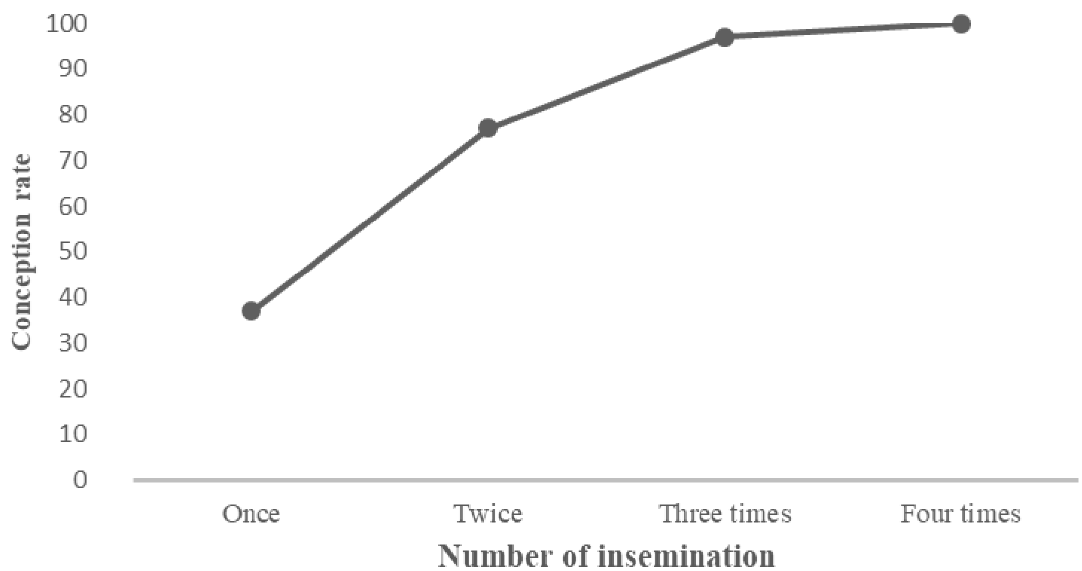

Figure *2.* Number of artificial inseminations per conception using extended fresh semen in smallholder rural pig farms.

in organized farms using two AIs per oestrus contrary to one AI per oestrus in field conditions in this study. Several authors including Lamberson and Safranski (2000), Kaysen (2013), Bortolozzo et al. (2005) and Kumar et al. (2014) suggest that return to oestrus is higher in pigs artificially inseminated once than the pigs artificially inseminated twice per oestrus. The lower performance of AI in field condition compared to organized farm is due to the factors related to semen handling and farm management (Kumar et al., 2014).

Extrinsic factors influencing the number of inseminations per conception

The effects of extrinsic factors on the number of IC are shown in Table 1. The number of IC was significantly lower in male household headed farms than in female household headed farms (1.38 ± 0.62 and 2.00 ± 0.83; $p < 0.05$, respectively). The difference could be explained by better farm management among male farmers compared to female farmers. In fact, Mbuza et al. (2016) reported that, in Rwanda, a large proportion of males is more involved in pig management activities such as feeding, cleaning, treating and record keeping compared to females; and good farm management is among the factors influencing fertility of pigs (Merks et al., 2000). Moreover, Visalvethaya et al. (2011) argue that the male farmers have better management skills than female ones, especially in oestrus detection, where the males detect heat better than their female counterparts. Similarly, Visalvethaya et al. (2011) reported that male managed farms present better fertility than female headed ones in Thailand.

The number of IC significantly varied ($p < 0.05$) with household head age, particularly between middle age (from 35 to 49 years) and old farmers (50 years and above). The lowest number of IC (1.59 ± 0.67) was observed in the farms managed by a group of 35 to 49 years old farmers while the highest number of IC (2.00 ± 0.90 and 2.04 ± 0.87) was observed in the farms managed by young and older farmers (Below 35 and above 50 years, respectively). This difference within age groups could be justified by the fact that age of the household head has a negative effect on the adoption of new technologies including AI (Dhraief et al., 2018; Bayei and Nache, 2014; Zanu et al., 2012) and innovations (Howley et al., 2012). The old farmers tend to stick to what they used to and hardly venture into new ways of doing things including AI (Bayei and Nache, 2014). The poor performances in young farmers could be explained by the fact that the young have fewer financial resources and are more interested in other activities compared to the other groups of age. Contrary, Visalvethaya et al. (2011) in Thailand reported that old farmers have better performances than young farmers. This difference between findings could be explained by the context specificity of the two areas.

The highest number of IC (2.02 ± 0.78) was observed in farms managed by single household heads, followed by the farms managed by widows with 1.82 ± 0.89 IC. The lowest number of IC (1.82 ± 0.70) was observed in married household headed farms. Although the difference was not significant ($p > 0.05$), the better fertility in married

Table 1. Effects of extrinsic factors on the number of inseminations per conception using extended fresh semen in rural smallholder pig farms.

Extrinsic factors		N	Mean	Std. Deviation
Sex of the household head	Male	16	1.38[b]	0.62
P = 0.01	Female	84	1.99[a]	0.83
Age of the household head	Young (less than 35)	11	2.00[ab]	0.90
P = 0.04	Middle (35 to 49)	32	1.59[b]	0.67
	Old (50 years and above)	57	2.04[a]	0.87
Marital status of the household head	Single	45	2.02[a]	0.78
P = 0.26	Married	10	1.60[a]	0.70
	Widow	45	1.82[a]	0.87
Experience of the household head	Five years and below	82	1.95[a]	0.83
P = 0.12	More than five years	18	1.61[a]	0.78
Education level of the household head	No formal education	3	1.33[ab]	0.58
p = 0.03	Primary	27	2.26[a]	0.86
	Secondary	41	1.85[ab]	0.88
	University	29	1.66[b]	0.61
Time of AI	07:00 to 12:00 am	37	1.97[a]	0.87
P < 0.01	12:00 to 16:30	31	2.19[a]	0.87
	After 16:30	32	1.50[b]	0.57
Distance from semen collection center to farm	Within 30 km	47	1.64[a]	0.67
P < 0.001	More than 30 km	53	2.11[b]	0.89
Floor material of pig house	Concrete	76	1.97[a]	0.88
P = 0.08	Timber	24	1.63[a]	0.58
District	Gicumbi	62	2.11[a]	0.87
P < 0.001	Rulindo	38	1.53[b]	0.60
Total		100	1.89	0.83

[a,b]Means in the same row with different superscripts significantly differ (P < 0.05).

household compared to widow and single household headed farms could be explained by the fact that the married have more financial means and are more responsible, compared to the widows and single, which enable them to improve pig farm management and result in better reproduction performances.

Although, in the present study, the difference was not significant ($p > 0.05$), the number of IC decreased with the experience of the household head in pig management. The farmers with less than five years of experience presented higher number IC per conception (1.95 ± 0.83) than the farmers with five years of experience and more (1.61 ± 0.78). Zanu et al. (2012) in Ghana reported that adoptions of improved technologies are associated with farming experience. Indeed, Visalvethaya et al. (2011) suggest that experience is crucial for pig reproduction particularly in heat detection.

Although the lowest number of IC (1.33 ± 0.58) was observed in the farmers who do not have any formal education, it significantly increased ($p < 0.05$) with education level of the household head. The household head with primary, secondary and university levels of education presented on average 2.26 ± 0.86, 1.85 ± 0.89 and 1.66 ± 0.61 AIs per conception. The present study results are consistent with the report by Bayei and Nache (2014) and Dhraief et al. (2018) who suggest that the adoptions of new technologies are associated with education of the household head. Indeed, Ajala (2007) in

Table 2. Effect of intrinsic factors on the number of inseminations per conception using extended fresh semen in rural smallholder pig farms.

Intrinsic factors		N	Mean	Standard deviation
Age of the female pig (years) p = 0.01	1	14	1.21 [b]	0.43
	2	66	1.95[a]	0.82
	3	16	2.13[a]	0.89
	More than 3	4	2.25	0.96
Parity of the female pig p = 0.01	1	12	2.42 [a]	0.79
	2	64	1.92[ab]	0.80
	3 and more	24[b]	1.54[b]	0.78
Breed of the female pig P = 0.50	Landrace	21	2.00 [a]	0.90
	Large white	13	2.15 [a]	0.99
	Pietrain	5	1.80 [a]	0.84
	Cross	61	1.80 [a]	0.77
Total	-	100	1.89	0.83

[a,b]Means in the same row with different superscripts differ ($p < 0.05$).

Nigeria revealed that the level of education is positively correlated with good farm management, thus, better fertilization or conception rate.

The number of IC significantly increased ($p < 0.05$) with the distance between the semen collection center and pig farm. The farmers located within 30 km from semen collection center presented the lower IC (1.64 ± 0.67) than the farms located at 30 km and more with 2.11 ± 0.90 IC. Moreover, the average number of insemination per conception was significantly higher ($p < 0.05$) in Gicumbi district than in Rulindo district (2.11 ± 87 and 1.89 ± 60, respectively). The negative influence of distance to insemination center on conception rate was reported during AI in cows (Nishimwe et al., 2015). On the contrary, Am-in et al. (2010) revealed that distance to AI center does not have negative effect on farrowing rate and non-return to oestrus. This difference could be due to the fact that return to oestrus after AI depends on the timing of insemination relative to the time of ovulation (Lamberson and Safranski, 2000). Hence, the long distance could compromise the precision in timing and risk to deterioration of semen due to shaking and increase in temperature, particularly when the inseminators use public transport. Eventually, difference within the two districts could be explained by the fact that the semen collection center of Kisaro is located in Rulindo district. According to Chanapiwat et al. (2014), the main limitation of the extended fresh semen is the short timing of its storage; therefore, the transport of the semen for long distances becomes difficult.

Although the difference was not significant ($p > 0.05$), the number IC varied with the type of floor material of pig house. The farms with floor in timber presented the lower average number of AIs per conception (1.97 ± 0.88) than the farm with concrete floor (1.63 ± 0.58). In the present case, slatted timber floor is easier to clean than concrete floor which justify lower number of inseminations per conception. According to Oravainen et al. (2006), better housing, particularly in terms of cleanness has a positive effect on fertility in female pigs. Dee (1992) suggests that poor environmental hygiene is responsible of urogenital track diseases which result in poor farrowing rates.

The number of IC significantly varied ($p < 0.05$) with the time of insemination. The pigs inseminated in the morning and evening (before 12:00 and after 16:30) showed the lowest number IC (1.97 ± 0.87 and 1.50 ± 0.57, respectively) while the pigs inseminated in the afternoon (from 12:00 to 16:00) presented the highest number of IC (2.19 ± 0.873). This difference could be explained by the cool temperatures observed during the morning and evening compared to the high temperature in the afternoon which can damage the fresh semen.

Intrinsic factors influencing the number of inseminations per conception

The intrinsic factors influencing the number of IC are shown in Table 2. The number of IC significantly increased ($p < 0.05$) with age of female pigs. The lowest number of inseminations per conception (1.21 ± 0.43) was observed in one-year old pigs while the largest number of IC (2.25 ± 0.83) was observed in female pigs aged of four years and more. This poor fertility in aged pigs could be associated with embryonic mortality. According to Vanroose et al. (2000), older animals have

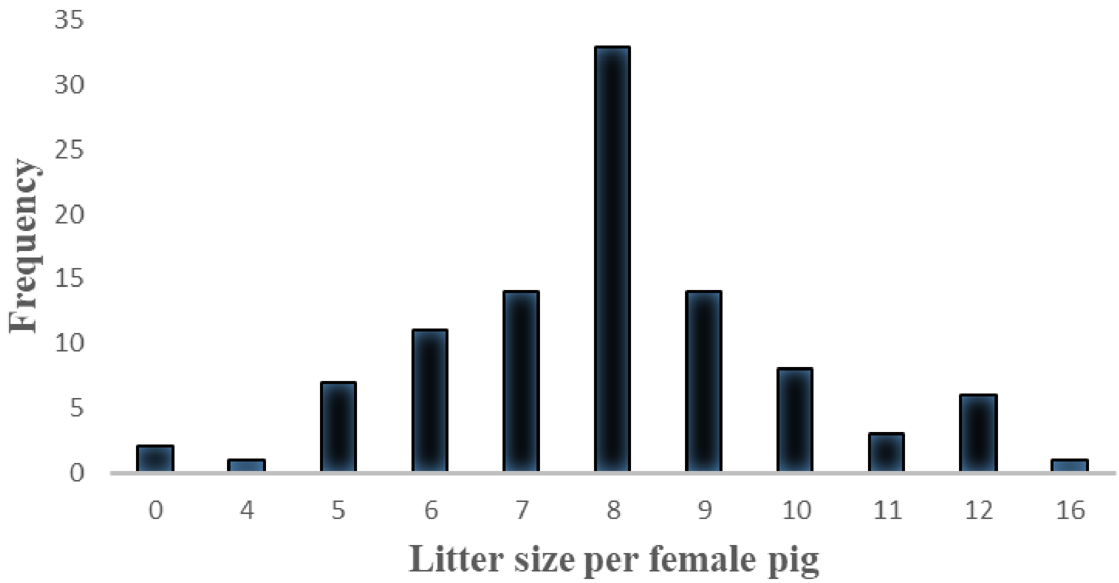

Figure 3. Litter size per female pig after artificial insemination (AI) using extended fresh semen in smallholder rural pig farms of Rwanda.

lower follicular activity and oocyte quality resulting in a decrease in embryos development. Indeed, the older animals are, the more the quality of the endometrium gets deteriorated.

The number of IC significantly (p < 0.05) decreased with parity of the female pig. The lowest number of IC (1.54 ± 0.78) was observed in the sows which had farrowed at least three times while the highest (2.42 ± 0.79) was observed in primiparous. The present findings are in line with the report by Kaysen (2013) and Vargas et al. (2009) who found the significant increase in fertility with parity. However, Kaysen (2013) argues that the conception rate decreases when the parity goes beyond seven.

Large white breed presented the highest number of IC (2.15 ± 0.99), followed by Landrace breed with 2.00 ± 0.89 IC. The lowest number of IC per conception (1.80 ± 0.837 and 1.80 ± 0.771) was observed in Pietrain and cross breeds, respectively. However, there was no significant difference (p>0.05) between the number of IC among the breeds. Similarly, Kaysen (2013) and Niyiragira et al. (2018) confirm that the breed of the female pig has no influence on the number of IC.

Litter size

The overall litter size was 7.94 ± 2.24 piglets per sow and 33% of all pigs gave birth to 8 piglets par sow (Figure 3). The litter size was comparable with 8.06 piglets per sow reported by Niyiragira et al. (2018) in Rwanda using imported fresh semen. The litter size was slightly higher than 7.2 piglets reported by Mbuza et al. (2016) in Rwanda using natural service. Similarly, Kumar et al. (2014) in India argue that litter size in higher when using AI than using natural service.

Effects of intrinsic factor on litter size

Table 3 shows the effect of intrinsic factors on litter size per female pig. The number of piglets per female pig significantly increased (p < 0.05) with parity of the female pig. Female with 1, 2 and 3 and more parities presented the litter size of 6.75 ± 3.17, 7.81 ± 1.94 and 8.88 ± 2.19, respectively. Lower ovulation rate and smaller uterine capacity than older sows are the possible reasons for smaller litter size in the first few parities (Foxcroft et al., 2006). These results corroborate with the report by Niyiragira et al. (2018) who observed that the litter size increased with parity. After the first parity, it increases gradually to a maximum in the third to fifth parity and slowly decreases through higher parities (Tummaruk et al., 2000). However, the age of the female pig did not show any influence on litter size (p > 0.05).

Pietrain breed presented the highest average litter size (8.80 ± 1.92). However, the difference was not significant. On the other hand, Niyiragira (2018) reported that Pietrain breed has significantly the largest litter size than landrace and cross between landrace and Pietrain breed.

Conclusions

The present study shows that the conception rate using AI of pigs in rural smallholder farms of Rwanda is lower

Table 3. Effect of intrinsic factors on litter size per female pig using extended fresh semen in rural smallholder pig farms.

Intrinsic factors		N	Mean	Std. Deviation
Female breed P = 0.86	Landrace	21	7.86[a]	2.06
	Largewhite	13	7.92[a]	2.36
	Pietrain	5	8.80[a]	1.92
	Cross	61	7.90[a]	2.34
Parity P = 0.02	1	12	6.75[b]	3.17
	2	64	7.81[ab]	1.94
	3	24	8.88[a]	2.19
Age P = 0.89	Between 1 and 2 years	80	7.93[a]	2.29
	Above 2 years	20	8.00[a]	2.08
Total		100	7.94	2.24

[a,b]Means in the same row with different superscripts significantly differ ($P < 0.05$).

compared to the other studies done elsewhere and can be influenced by intrinsic and extrinsic factors. Among the intrinsic factors influencing pregnancy rate, parity had a positive effect on pregnancy rate. For the extrinsic factors, the male managed farms presented better conception rates than female managed farms. Farms managed by middle aged household heads presented better conception rates than the farms managed by young and old farmers. Education level of the household head had positive effect on conception rate. Inseminating in morning and evening results in better pregnancy rate than inseminating in the afternoon. Reducing distance between insemination center and the farm had positive effect on conception rate.

From the results, it is recommended to improve AI procedure in order to reduce the number of artificial inseminations per conception. This could be possible, for example, through increasing the number of AI centers in order to reduce the distance between the households and semen collection center, thus, optimize the success of AI in Rwanda. Indeed, more attention should be made regarding the pig farms managed by old, young, female farmers and farmers with only primary education to optimize the success of artificial insemination in pigs.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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