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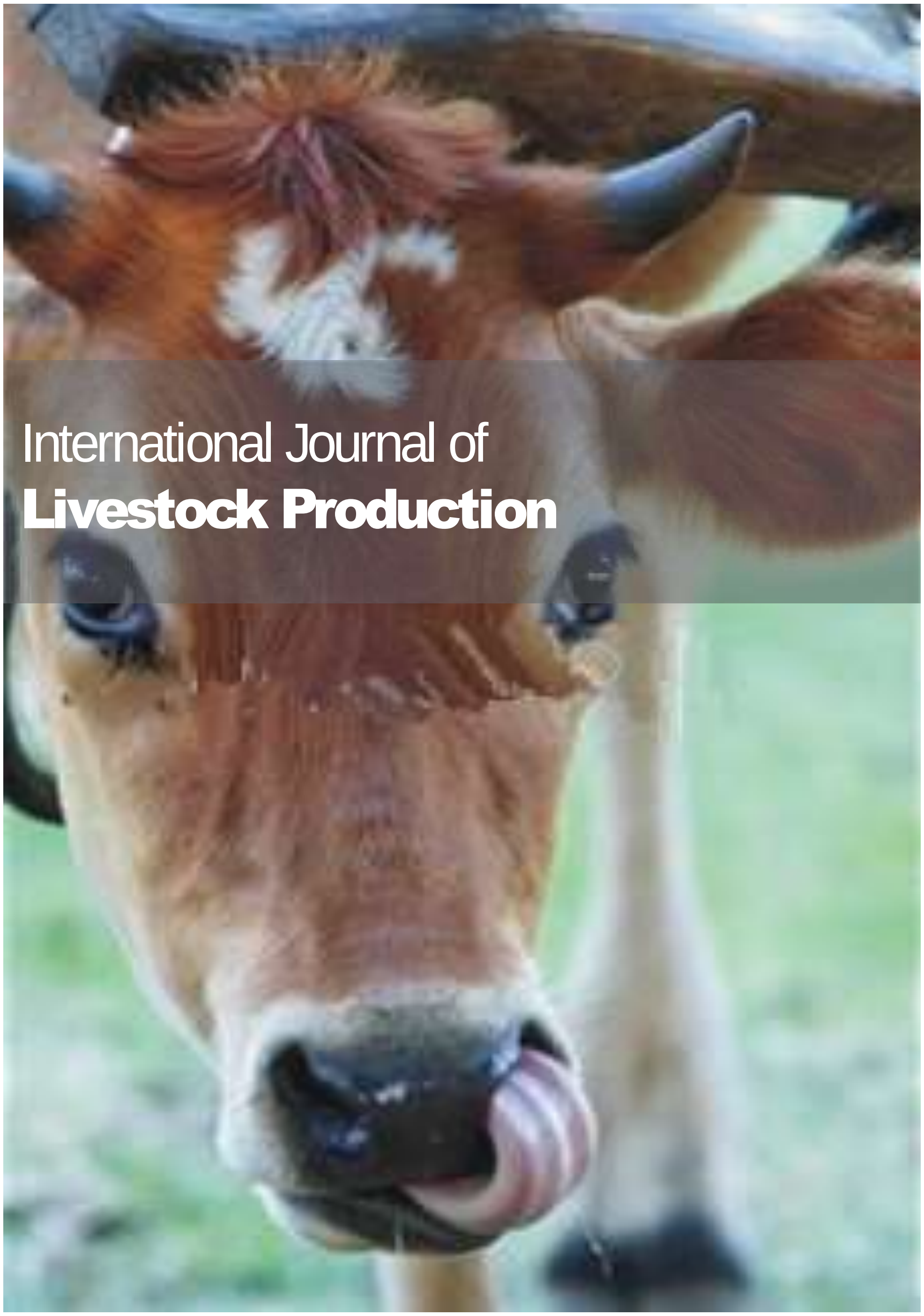

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Review

Suboptimum reproductive performance among dairy herds in Uganda

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Suboptimum reproductive performance affects the overall profitability of dairy herds. In order to manage this condition, there is need to clearly understand the different forms in which it presents, as well as its possible risk factors under the Ugandan context. This review study was conducted to highlight the different forms of suboptimum reproductive performances among Ugandan dairy herds through literatures from previous studies. At the same time, underscores the coexistence of risk factors of suboptimum reproductive performance among the same dairy herds in Uganda. In Uganda, dairy cattle experienced pathological postpartum cycling patterns, delayed calving to first service intervals, long calving intervals, low pregnancy rates and high abortion rates. Inadequate nutrition, management errors and infectious genital diseases such brucellosis and bovine viral diarrhea were common in these herds. There is need to undertake studies that link the different forms of suboptimum reproductive performance and their possible risk factors.

Key words: Suboptimum reproductive performance, postpartum pathological anestrous, infectious genital diseases.

INTRODUCTION

Dairy production is the single largest agricultural sector in the world. The sector accounts for 14% of global agricultural trade, with milk being the most traded agricultural product (Wang and Li, 2008). In Uganda, the dairy industry is estimated to contribute about 50% of the total output from the livestock subsector (Ekou, 2014). Efforts to improve dairy production in the country have been enhanced through introduction of Holstein Friesians as the main temperate dairy breed (Galukande, 2010). However, the dairy sector in Uganda is still facing many challenges, including low dairy herd productivity (Kabirizi et al., 2006).

Dairy herd productivity is mostly determined by the cow's reproductive performance as it influences the efficiency of milk production and the number of calves produced in the cow's lifetime (Plaizier et al., 1997).

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Among the reproductive performance measures, that is, age at first calving, number of service per-conception, calving to first service interval (CSI), calving interval (CI) and pregnancy rates are the commonly used indices on most dairy farms. Suboptimum dairy cow reproductive performance is typified by low pregnancy rate, increased number of service per conception, delayed postpartum intervals to first oestrus, and long calving intervals, among others (Esslemont, 1992). As a result, suboptimum reproductive performance leads to fewer calves born during the productive lifetime of the cow, a high involuntary culling rate, veterinary costs, all of which erodes the profitability of the dairy enterprise. Numerous factors such as inadequate nutrition, infectious genital diseases, environmental stressors, as well as cow-based factors including breed, parity and level of milk production, have been associated with occurrence of suboptimum reproductive performance among dairy cattle.

In Uganda, several studies have reported the occurrence of suboptimal reproductive performance among dairy herds (Mugisha et al., 2014; Ongubo et al., 2015). In the same dairy herds, the existence of possible risk factors including management errors, poor nutrition, infectious genital diseases and heat stress, has also been documented. However, fewer studies have established the associations between the risks factors of suboptimum reproductive performance and its occurrence among dairy herds in Uganda. Based on this background, the different forms of sub-optimum reproductive performances were reviewed among dairy herds in Uganda. Belatedly, the risk factors associated with suboptimum reproductive performance are highlighted, with a view of guiding future studies aimed at linking these factors and the occurrence of reproductive disorders among dairy herds in Uganda.

FORMS OF SUBOPTIMUM REPRODUCTIVE PERFORMANCE AMONG DAIRY HERDS IN UGANDA

Worldwide, suboptimum reproductive performance has been recognized as a major production bottleneck among dairy herds. As a result, several researchers have reported different indicators of reproductive inefficiency in dairy herds. In this review, published data was used to document the major indicators of dairy reproductive inefficiency under Ugandan conditions.

Pathological postpartum cycling patterns

In practice, it is recommended for dairy producers to set a voluntary waiting period (VWP) of 60 to 65 days after calving during which a cow is not bred even when it comes on heat. This is meant to allow the reproductive system of a cow to achieve full recovery from the previous calving. Immediately after VWP, cows are required to be bred on the subsequent heat so as to conceive within 80 to 85 days after calving (Dayyani et al., 2013). This is based on the fact that the goal of cow-calf operations is to obtain one calf per cow per year, given that the gestation length is 280 days.

Pathological postpartum cyclicity is a functional disorder characterized by failure of a postpartum cow to resume ovarian function, ovulate and establish pregnancy within 80 to 85 days after calving. At farm level, cows with this condition have long calving to first service intervals, extended calving intervals, low submission rates, low pregnancy and calving rates (Lucy, 2001). The inability to meet the optimal dairy reproduction performance targets, compromises the overall profitability of the farming business. Although the causes of this condition include congenital defects, physiological disturbances/imbalances, management errors and infectious agents, the underlying feature is the deviations in hormones that regulate reproductive activities among affected animals. Among dairy farms, pathological postpartum anestrus tends to affect individual animals or a particular sub-group of animals in the herd. The main forms of pathological postpartum anestrus include: sub estrus, true anestrus, ovulatory defects and cystic ovarian disease (COD) (Max, 2010).

In Uganda, a study (Kanyima et al., 2014) revealed that up to 81.4% of dairy cows in peri-urban Kampala resumed cyclicity within 60 days post calving. However, only 23.7% of the daily cows maintained cyclicity and were therefore the only ones that could achieve the recommended 365-day calving interval. In this study, poor nutrition as well as management errors such as manual extraction of after-births were associated with occurrence of pathological postpartum cyclicity patterns. Therefore, proper husbandry practices especially management of postpartum dairy cows need to be emphasized through training of farmers at household levels.

Long calving intervals

Calving interval (CI) refers to the number of days between successive parturitions (calvings). Several studies have examined the economics of maintaining a regular CI on milk production and overall dairy profitability. In these studies, the need to review all major dairy herd management practices as well as costs of producing milk are highly emphasized before deciding the length of CI to adopt (Arbel et al., 2001). Under normal circumstances, the acceptable CI is when a dairy cow calves after every 12 months.

From the literature reviewed (Table 1), there was a wide variation in the calving intervals among breeds and production systems in Uganda. Several studies have reported CI ranging from 13 to 36.5 months among dairy

Table 1. Summary of calving intervals (CI) among dairy cattle herds in Uganda.

Breed	Production system	Location	Calving interval (months)	Source
Friesian and their crosses	Intensive and semi-intensive	Central Uganda: Masaka District	16.8	Nakiganda et al. (2006)
Friesian and Friesian crosses	Intensive, semi intensive and extensive	Central Uganda: Mukono, Kayunga, Luweero, Nakasongola, and Masaka Districts	14.4	Mugisha et al. (2014)
Holstein × Ankole crosses	Extensive	South Western Uganda: Kiruhura	15.3	Galukande (2010)
Ankole	Extensive	South Western Uganda: Kiruhura District	13	Kugonza et al. (2011)

Table 2. Summary of pregnancy rates among cattle in Uganda.

Breed	Production system	Location	Breeding method	Pregnancy rates (%)	Source
Indigenous: Ankole, Boran and Zebu	Semi-intensive	Central Uganda	Embryo transfer	58.5	Cumming et al. (1994)
Friesian and Friesian crosses	Extensive	South Western Uganda	Timed	0-50	Kwon et al. (2017)

small holder dairy farming systems in Central Uganda (Mugisha et al., 2014; Nakiganda et al., 2006). In the same central Uganda region, Mugisha et al. (2014) reported an average calving interval of 14.4 months among dairy herds . However, a study by Kugonza et al. (2011) reported a shorter CI among Ankole cattle in Western Uganda, which could be attributed to their adaptation to the environment and having no postpartum lactation stress. The calving intervals among dairy cattle in Uganda were comparable to those reported in other sub-Saharan African counties especially Kenya and Ethiopia. Nevertheless, all studies reveal extended calving intervals among the breeds and production systems in Uganda. As earlier noted, the calving to conception interval should not exceed 80 to 85 days if a farmer is to realize a 12 months calving interval. Therefore, interventions aimed at shortening the calving to first service interval (CSI) will enable a dairy farmer to achieve an optimum calving interval.

Low pregnancy rates

Pregnancy rates are universally regarded as the most important measures of breeding efficiency used to monitor reproductive performance among dairy herds (Chebel et al., 2004). This is in view of the fact that this parameter is easy to measure and less biased compared to CI, which requires the data of two subsequent calving. Pregnancy rate measures the percentage of cows eligible to be bred that actually get pregnant in a given time.

In Uganda, fewer studies on pregnancy rates among dairy cattle herds have been conducted. This is mainly due to the fact that fewer farmers keep breeding records. Besides, natural mating is the mostly practiced breeding method which makes it impossible to know exactly when the cows were mated. A survey on the use artificial insemination (AI) among dairy herds in peri-urban Kampala reported low pregnancy rates (Eklundh, 2013). The reported low pregnancy rates were based on farmers' responses, recorded breeding repeats and pregnancy wastages. On the other hand, controlled breeding experiments, as shown in Table 2, recorded higher pregnancy rates. De Vries (2006) observed that in order to achieve a high pregnancy rate of at least 25%, at least, both 65% service rate and 35% conception rate should be realized. Management interventions aimed at minimizing heat and environmental stress, adequate nutrition and control of infectious diseases are important to ensure the high pregnancy rates. Correspondingly, good animal management practices such as adequate nutrition and deworming reported in the Ugandan experimental breeding program (Cumming et al., 1994), could explain the attained higher pregnancy rates.

High abortion rates

In dairy cattle operations, abortion is defined as expulsion of the fetus between the age of 42 days and approximately 260 days' of gestation (Hovingh, 2009). Abortions cause significant morbidity and mortality as well as heavy financial losses to the affected dairy herds. The effects of abortions include low pregnancy and low calving rates, reduced milk production and pre-mature culling, ultimately reducing overall dairy herd productivity (Hovingh, 2009). In view of the significant effects of this reproductive disorder, the abortion rate is commonly used to monitor reproductive performance among dairy herds. There are numerous causes of abortion among dairy cattle herds which include infectious agents (bacteria, viruses, protozoa, and fungi), toxic agents, heat stress, and genetic abnormalities. It should be noted that most dairy herds suffer an abortion rate of 1 to 5%; and this is often considered normal (Lucchese et al., 2016). However, if the abortion rate increases to above 5%, then the manager should begin to make efforts to investigate the cause. In Uganda, a herd level abortion rate of 30 to 35% has been reported among urban and peri-urban dairy farms (Benon et al., 2015). Furthermore, a study by Magona et al. (2009) revealed that the abortion rate was 5.4 to 23% among zero-grazed and pastoral systems in Uganda. This abortion rate is far beyond the recommended tolerable level and there is therefore a need to investigate the causes and come up with intervention strategies to address this challenge.

RISK FACTORS OF SUBOPTIMUM REPRODUCTIVE PERFORMANCE AMONG DAIRY HERDS IN UGANDA

To address the challenge posed by suboptimum reproductive performance in dairy herds, it is important to establish its plausible risk factors. Based on published data, a number of risk factors linked to different contributors of suboptimum reproductive performance in Ugandan dairy herds were highlighted.

Inadequate nutrition

Nutrition plays a significant role in dairy cattle reproductive performance. Nutrition influences reproductive performance by altering the concentrations of hormones and metabolites at all levels that regulate reproduction, that is, the hypothalamus-pituitary-ovarian axis. In particular, nutrition modulates the generation of hypothalamic gonadotropin releasing hormone (GnRH) pulse that is responsible for luteinizing hormone (LH) pulsatility and eventual ovulation. Inadequate dairy cow nutrition, especially low energy intake, precipitates a state where energy demand for lactation and maintenance exceeds dietary intake. Affected cows have low plasma glucose, reduced LH pulse and impaired ovarian function, leading to suboptimum reproductive performance. Consequently, proper nutrition has been reported to advance puberty, reduce postpartum anestrus period and improve conception and pregnancy rates.

Several studies have reported poor nutrition among dairy herds in Uganda (Kiggundu et al., 2014; Nakiganda et al., 2006). This has been attributed to the fact that most dairy herds depend entirely on rain-fed natural feeds and pastures, with a few engaging in fodder production and conservation. As a result, the dairy animals are unable to meet the nutritional needs which translate into low milk production and reproductive performance. A study revealed that about 30.7% of dairy cows in Uganda suffered pre-partum negative energy balance (Dickson et al., 2014). The same study reported that 18.8% of the dairy cows in Uganda had postpartum subclinical ketosis. Negative energy balance and subclinical ketosis have been reported as major causes of high incidences of postpartum diseases as well as suboptimal dairy reproductive performance. Furthermore, feed scarcity due to drought (Nakiganda et al., 2006), insufficient feed sources (Kiggundu et al., 2014), suggest that dairy cows in Uganda do not get enough nutrients to meet their production and reproduction potential.

Dairy farm and herd management errors

Dairy farm and herd management errors are caused by poor workmanship by the managers and cattle handlers themselves. These errors include failure to keep records, misidentification of animals, poor heat detection, and poor management especially during the post parturient interval (Mugisha et al., 2014). It is important to note that studies on management causes of sub-optimum reproductive performance especially general husbandry practices have been the most emphasized in Uganda. Kanyima et al. (2014) reported management errors that include calving in unhygienic environments, manual extraction of cow placentae shortly after calving and traditional practices of managing obstetrical cases among dairy farmers in peri-urban Kampala. These practices predispose to post parturient disorders such as endometritis, metritis and retained afterbirth, all which adversely affect reproductive performance of dairy cows. Poor record keeping has also been reported among dairy farms. This is attributed to the fact that most farmers are illiterate, while others find record-keeping as laborious, time consuming and meaningless. Failure to keep records lead to misidentification of animals, inability to follow up herd performance and inefficiency in making decisions. Moreover, a study by Mugisha et al. (2014) reported record keeping as a key factor that determined the success of heat detection and artificial breeding services among dairy farms in central Uganda.

Infectious genital diseases

Suboptimum reproductive performance caused by infectious genital diseases remains a serious challenge

Table 3. Summary of prevalence of infectious genital diseases among dairy cattle herds in Uganda.

Disease	Location	Prevalence (%)	Sources
	South western Uganda	14-29[a]	Miller et al. (2016)
	Peri-urban and urban Kampala	5.0[a], 6.5[b]	Makita et al. (2011)
	South Western Uganda	15.8[a], 55.6[b]	Bernard et al. (2005)
	South Western Uganda	5.6[a], 25[b]	Oloffs et al. (1998)
	Central Uganda (Pastoral areas)	34[a], 100[b]	Magona et al. (2009)
Brucellosis	Eastern Uganda	3.3[a], 5.5[b]	Magona et al. (2009)
	Northern Uganda (Gulu)	6[a], 19[b]	Mugizi et al. (2015)
	Eastern Uganda (Soroti)	9.1[a], 46[b]	Mugizi et al. (2015)
	Eastern Uganda (Soroti)	15.4[a]	Egaru et al. (2013)
	Soroti Agro-pastoral	16[a]	Ocaido et al. (2005)
	Country-wide (Uganda)	12[a]	Mwebe et al. (2011)
	Urban Kampala	2.8[a], 10.7[b]	Jönsson (2013)
	Western Uganda (Fort portal and Kasese and Kabarole	16.7[b]	Wolff et al. (2017)
Bovine viral Diarrhoea (BVD)	Peri-urban and Urban Kampala	23.4[a], 39.3[b]	Jönsson (2013)
	Western Uganda (Fort portal and Kasese and Kabarole	53.4[b]	Wolff et al. (2017)

[a]Individual animal prevalence; [b]Herd prevalence.

among dairy herds (Campero et al., 2003). The prevalence of these infections varies across herds and production systems. Brucellosis, BVD, IBR, Trichomoniasis and Vibriosis are known to be among the most important infectious genital conditions in many parts of the world. These conditions cause several reproductive disorders that include embryonic death, repeat breeding, abortions, stillbirth and uterine infections. In Uganda, several studies (Table 3) have reported the existence of infectious genital diseases among dairy herds. However, there are wide variations in occurrences of these diseases in different parts of the country. Of all the infectious genital diseases, Brucellosis has been the mostly studied with several researchers reporting prevalence ranging from 0 to 100% among dairy herds in Uganda. On the other hand, BVD sero-prevalence of 39% was reported among dairy herds in urban and peri-urban Kampala (Jönsson, 2013). Although the prevalence of IBR has not been reported in Uganda, several studies in other African countries have reported more than 50% prevalence among cattle herds. A recent study reported a herd prevalence of up to 81.8% among the major milk sheds in Ethiopia (Sibhat et al., 2018). Other studies have reported IBR prevalence levels of up to 74.47% in South Africa (Njiro et al., 2011), and 69% among cattle herds in Ghana (Adu-Addai et al., 2012). The fact that most African countries have similar agro-ecological conditions and farming systems suggests that these diseases may be significant in Uganda as well. It should be noted that fewer studies have been conducted to associate the prevalence of infectious genital diseases and occurrence of suboptimum reproductive performance conditions in Uganda. However, a study by Magona et al. (2009) reported high incidence of abortion rates among *Brucella* sero-positive dairy cattle herds in Uganda. Other infectious genital diseases like Trichomonisis and Vibriosis have not been studied in Uganda.

CONCLUSION

Suboptimum reproductive performances documented in dairy cattle throughout the world, are also observed among herds in Uganda. This is mainly based on farm information and the few highlighted studies. There is a need for further studies to establish and estimate reproductive parameters among dairy herds in Uganda. Such studies should incorporate in the risk factors of suboptimum reproductive performances. It is based on such findings that informed management interventions aimed at improving reproductive performance of dairy cattle in Uganda can be implemented.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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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*

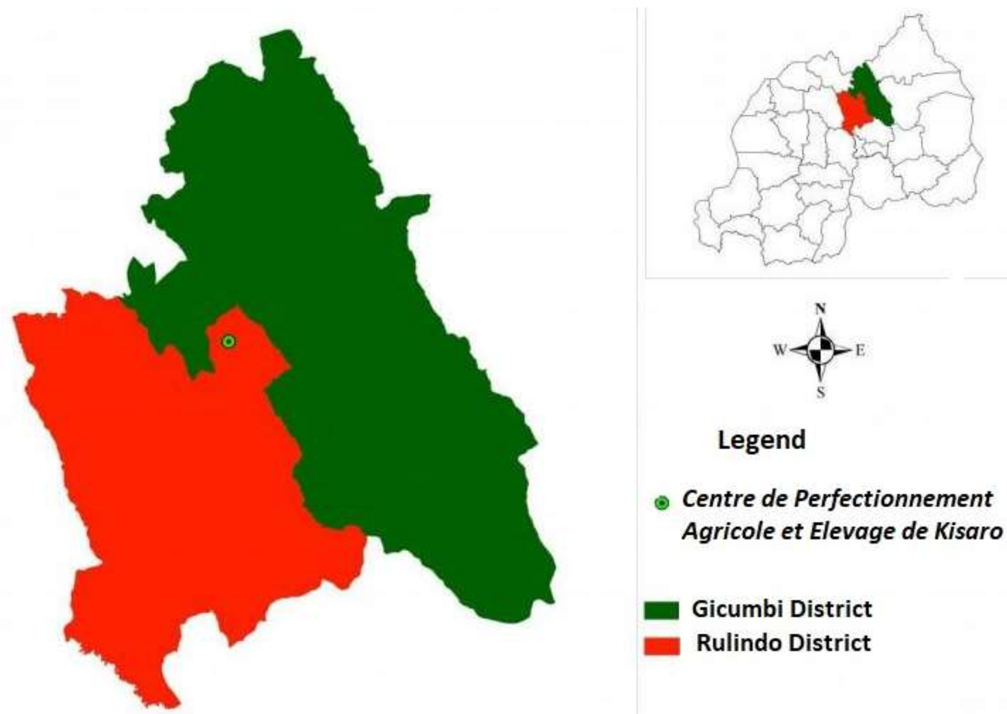

Figure 1. Location of Gicumbi and Rulindo districts and Centre de Perfectionnement et de Promotion Agricole de Kisaro (CPPA).

*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

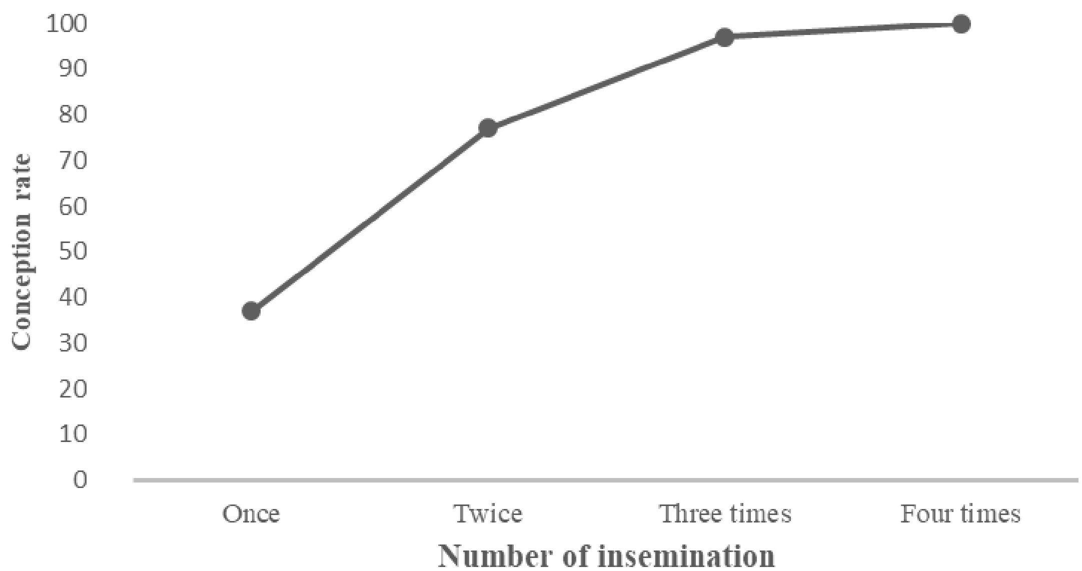

Figure *2.* Number of artificial inseminations per conception using extended fresh semen in smallholder rural pig farms.

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

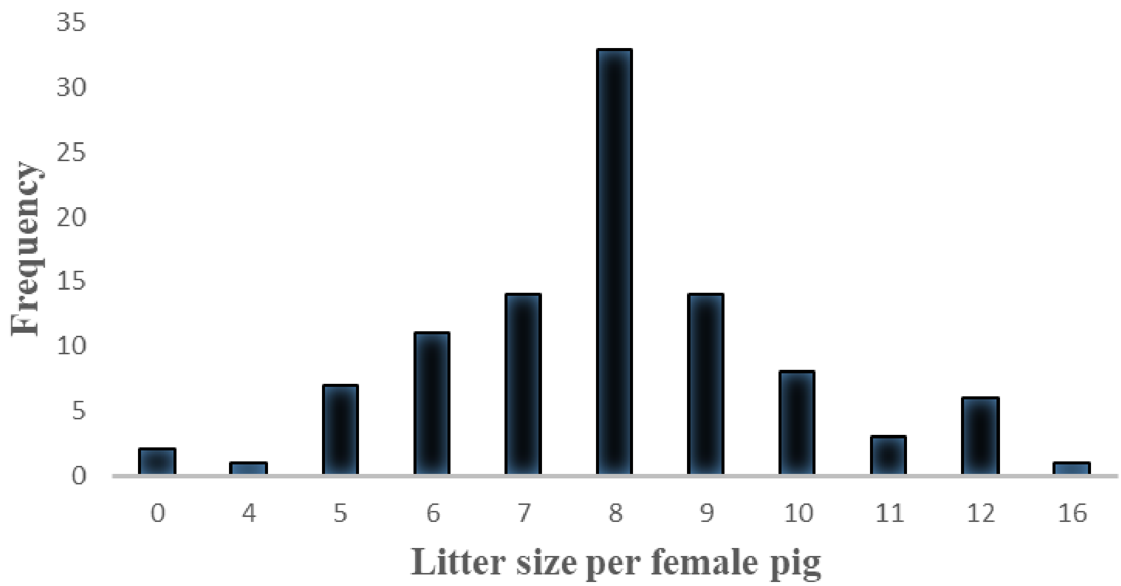

Figure 3. Litter size per female pig after artificial insemination (AI) using extended fresh semen in smallholder rural pig farms of Rwanda.

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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Carcass and meat quality characteristics of two hair type breed lambs fed *tef* (*Eragrostistef*) straw ensiled with effective micro-organisms and supplemented with concentrates

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The experiment was conducted with the objective of studying the carcass characteristics and meat quality of Arsi-Bale lambs (AB) and Afar lambs (Af) fed on tef straw (TS) ensiled with effective microorganisms and supplemented with concentrate. The experimental design was complete randomized block with two factors having 7 replications. Each lamb was fed on TS silage alone, or supplemented with either wheat bran Bokashi alone or mixed with noug seed cake. The results indicated that, except for chilling loss and the dressing percentages the AB were better than the Af in all the carcass characteristics that were improved by supplementation. Most of the carcass linear measurements were influenced only by diet which made the supplemented lambs performed (p>0.05) better (p<0.05) than the control. The meat physicochemical and chemical characteristics were similar for both except L* value and fat content were higher for Af. Control lambs had higher (p<0.05) meat pH_{24}, moisture and ash contents, and lower fat content. The eating qualities were similar (p>0.05) for both breeds, though better (p<0.05) for the supplemented. It is concluded that compared to the Af the AB can produce similar quality but better lean meat yield.

Key words: Bokashi, Tef straw silage, meat quality, morphometric carcass measurements, sensory evaluation, physicochemical characteristics.

INTRODUCTION

Ethiopia has high sheep genetic diversity that has been developed by natural selection (Galal, 1983). Meat

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production is the most important function of these animals in Ethiopia. *Washera*, *Bonga*, *Horro*, *Arsi-Bale* and *Adilo* are among Ethiopian sheep breeds that produce mutton well in good environmental conditions while Afar and Black Head *Somali* are good producers of mutton even in environment with limited feed and water (Gizaw, 2008). The demands for their meat in the country especially during religious festivals is very high (Amha, 2008).

This demand had made sheep husbandry important in pastoral, agro-pastoral and mixed farming areas as a source of cash income, food security, household meat consumption, live animal savings and manure supply (Hassen and Tesfaye, 2014; Tibbo, 2006). Furthermore, Ethiopia's commercial red meat industry, mainly of small ruminants, has made remarkable progress to date and shows considerable growth potential for the future (U.S. Embassies Abroad, 2017; AGP-LMD, 2013). As a result, the Ethiopian Government, as part of its livestock master plan, intends to transform the livestock sector and increase production and exports of meat (U.S. Embassies Abroad, 2017).

Despite the growing market demand, the chronic challenges that livestock production is facing have kept the benefit at minimal (Amha, 2008). Among the challenges, one which is aired loudly is problem of highland sheep mutton's short shelf life (darkening) (Abebe et al., 2010) that limits export to the lowland sheep only (Akililu et al., 2005). Additionally, meat from Ethiopia could not attract a high price as a result of lacking established grades and brands of Ethiopian identity in the export market. Hence, producers have no incentive to raise animals producing high-quality carcasses (Amha, 2008). There are only a few studies aimed at elucidating the causes and possible remedies for the dark cut meat problem held on export market targeted sheep breeds (BHO from lowland and Arsi-Bale from highland (Merera et al., 2015; Merera et al., 2013; Abebe et al., 2010; Merer et al., 2010) though the Afar breed was also important export sheep. These studies focus only on length of rest and feeding after transportation, assuming that transportation is the major responsible factor. Yet, as important as the transportation stress, nutrition and feeding regimes especially provision of antioxidant are reported to be causes and remedies for dark cutting meat (Ponnampalam et al., 2017). In this regard, Effective Microorganisms (EM) as biological inoculants were believed to improve nutritional quality of poor quality feed resources (Balogun et al., 2016; Samsudin et al., 2013; Yonatan et al., 2013).

EM is a mixture of aerobic and anaerobic microorganisms, specifically, lactic acid bacteria, yeast, and photosynthetic bacteria, fermenting fungi and actinomycetes that survive together synergistically and fight off pathogens and rotting microorganisms (Higa and Wididana, 1991, Talaat et al., 2015). The growth of pathogenic microorganisms is checked by the inhibiting effect of lactic acid as a result of reduced pH, while the yeast feed the other microbes by producing many food substances like amino acids and polysaccharides. Phototrophic bacteria also play an important role in nitrogen and carbon cycles metabolic systems (Higa and Wididana, 1991; Talaat et al., 2015). Therefore, the symbiosis existing among EM microbes can prevent the putrefactive and pathogenic effect of bad microorganisms and assure good quality silage preventing them from inferior quality feed resources. Furthermore, fermentation of plant materials with EM was proven to improve fiber digestibility (Kannahi and Dhivya, 2014). However, as its CP and energy contents are very low (Tibebu et al., 2018), the fermented teff straw alone cannot satisfy the nutrient requirement of the lambs. As a result, protein as well as energy supplements needs to be incorporated into the fermented tef straw basal diet. Hence, the present experiment was conducted with the objective to study the carcass characteristics and meat quality of *Arsi-Bale* and *Afar* sheep breed lambs fed on *tef* straw ensiled with effective microorganisms and supplemented with concentrates under stall feeding condition.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Addis Ababa University, College of Veterinary Medicine 45 km South -east of Addis Ababa, Ethiopia. It has an altitude of 1900 m above sea level and is located between 8.44°N latitude and 39.02°E longitude. Its average maximum and minimum temperature and annual rainfall are 24.3, 8.9°C and 851 mm, respectively (Getahun, 2014).

Experimental design, animals, treatment diets and their feeding management

Twenty-five lambs of Afar(Af) and Arsi-Bale(AB) breeds were purchased from the respective local markets. They were intact male with the age of 6-9 months.. Dentition and physical appraisal for proper development were the main criteria used for the selection and purchase of the lambs. The purchased lambs were then transported to the study site and acclimatized for fifteen days during which, they were drenched against internal parasites, sprayed against ecto-parasites and vaccinated against anthrax and ovine pasturolosis.

Twenty-one lambs selected for the study from each breed were weighed and divided into seven different weight groups, which represent the replications (blocks) in a randomized complete block design in two factorial arrangement (breed and diet). All animals from each block of each breed were allocated to the experimental diets at random. Thereafter, they were provided with the treatment diets for a fifteen day adaptation period. During the experiment, the lambs were housed in individual animal pens equipped with feeding and watering troughs cleaned every day before offering feed. All animals had free access to water and Rursal RQ mineral blocks (Tecnozoo, https://tecnozoo.it/en/product, Italy). There were three treatment diets, namely, *tef* (*Eragrostistef*) straw silage inoculated with effective microorganisms (EM) offered free choice without supplementation (D1, control); D1 supplementated with wheat bran bokashi (WBB) only (D2) and D1 supplementated with a concentrate feed prepared from WBB and Noug seed cake (NSC,

Table 1. Dry matter (g kg^{-1}) and nutrient (g kg-1DM) composition and estimated ME (MJ kg-1 DM) of experimental feed.

Parameter[a]	Experimental Feed[b]			
	TSS	WBB	NSC	Concentrate mix
DM	282.60	849.00	907.70	874.80
ash	91.00	56.90	153.40	88.30
OM	909.90	943.10	846.60	786.50
CP	58.10	173.10	322.10	211.00
EE	9.60	31.60	42.30	31.90
NDF	792.70	473.10	451.80	405.40
ADF	439.20	386.20	263.30	288.80
IVDOMD	325.60	577.13	329.11	822.92
ME	5.23	8.39	3.93	5.55

[a]ADF=Acid detergent fiber; CP=Crude protein; DM=Dry matter; EE= Ether extract; IVDOMD (g kg-1DM)=In-vitro digestible organic matter in dry matter; OM=Organic matter; NDF=Neutral detergent fiber; ME=Metabolizable energy.
[b]TSS=TS silage; NSC=Noug seed cake; WBB=Wheat bran bokashi

D3). This experiment is a follow up on of a research project comprising TS fermentation (silage making), feeding and digestibility trials. Hence, the EM activation and extension procedures, making of *tef* straw silage (TSS), WBB preparation and nutrient composition of the experimental feeds (Table 1) are discussed elsewhere (Tibebu et al., 2018, 2019). From the TS fermentation experiment, 21 days of ensiling period with 500 mL EM/ 1 kg TS (as feed basis) was found better for making nutritionally good quality TSS. As a result, it was used for the feeding and digestibility trials and consequently in this experiment. The WBB was prepared according to the manual of the EM supplier company. The TSS was prepared by inoculating wet TS with EM solution at a rate of 500 mL/kg and ensiling it for 21 days under shade. WBB was prepared by inoculating dry wheat bran (WB) with EM solution at a rate of 400 mL/kg and ensiling it for 21 days.

The formulation and offer of the concentrate was done to fulfill the minimum CP requirement of the lambs on D_2 and D_3 and offered in a separate trough being divided into two equal portions and provided at 08:00 and 18:00 h before offering basal diet. In order to maintain fulfilling the requirement of the lambs, the feed formulation and offer amount were adjusted fortnightly following their weight change.

Slaughter of animals and carcass measurements

At the end of the feeding and digestion trials, all animals were withdrawn from feed overnight with free access to water, and slaughtered with halal procedure after recording weight just before slaughter (slaughter body weight, SBW). The blood weight was determined as SBW less body weight after bleeding. After the removal of digestive tract and non-carcass components, hot carcass weight (HCW) was recorded including tail fat. Edible and inedible offal components and all non-carcass fat depots (kidney, omental and mesenteric fats) were weighed and recorded. The weight of the digestive tract was recorded while full and empty. Thus, weight of gut-content was computed as the difference between full and empty weights of digestive tract. Empty body weight (EBW) was determined as SBW less gut contents. After the tails were removed and their weight recorded, the carcass was kept in a chilling room (4 to 5°C) for 24 h. Water loss during chilling was considered as carcass chilling shrink (CS) and expressed as percent HCW. Hot carcass dressing percentage on SBW basis(HCDP), cold carcass dressing percentage on SBW basis (CCDP) and cold carcass dressing percentage on EBW basis (DPEB) were calculated as (HCW/SBW)*100; (CCW/SBW)*100 and (HCW/EBW)*100, respectively. Ribeye area (REA) was measured on cold carcass at the 12/13th rib position using transparent paper.

The left and right REA area was traced onto a square paper which was placed on the transparency; the area of the squares (0.25 cm^2 each) that fell within the traced area was measured and those partially outside were estimated and average of the two sides was taken as the REA. All morphometric measurements (anterior and posterior buttock circumference (ABC, PBC), buttock width (BW), carcass length(CL), chest width (CW), leg length (LL), shoulder width (SW) and thorax circumference (TC) were also measured on chilled carcass. Leg compactness (LC) and carcass compactness (CC) were calculated as BW/LL and CCW/CL, respectively.

Meat sample preparation

On both sides of the chilled carcass, a cut was made on the back between the $8^{th}$and 12^{th} rib bone to obtain the *Longissimus dorsi* muscle on which the physicochemical, chemical and sensory eating quality analyses were performed. A total of four samples (two from each side) with a weight ranging from 30 to 63 g were collected. The left side samples were used for determination of color, pH and chemical composition while the right side samples were used for sensory analysis. After taking the color and pH the left side samples were vacuum packaged and stored frozen (<-20°C). The right side samples were aged for 5 days in chilling temperature (4 to 5°C) and stored frozen until evaluated. The frozen samples were thawed overnight in a refrigerator at 4°C before evaluations were commenced.

Determination of physicochemical characteristics of meat

The bag drip loss (BDL) of the meat samples was determined by deducting the weight of the samples after ageing and freezing from the weight of the sample before packing (Pérez-Munuera et al., 2009). The pH measurements were made 45 min (pH_{45}) on the carcass in the *Longissimus dorsi* muscle before chilling and 24 h (pH_{24}) post-mortem on samples taken from chilled carcass using a portable meat pH-meter (HI99163, HANAN instruments) having a sharp penetrating blade over the electrode. The probe was cleaned with distilled water and calibrated with pH 4.1 and 7.1 buffer

Table 2. Carcass characteristics and yield of Arsi-Bale and Afar lambs fed on sole FTS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEMe	Breed (B)[e]		SEM[e]	p-value		
	D1	D2	D3		Af	AB		T	B	T x B
SBW (kg)	16.41[b]	22.59[a]	24.11[a]	0.67	18.68y	23.20x	0.55	0.00	0.00	0.49
EBW (kg)	11.65[b]	18.27[a]	19.73[a]	0.56	14.89y	18.05x	0.45	0.00	0.00	0.36
HCW (kg)	5.46[b]	9.01[a]	10.16[a]	0.42	7.44[b]	8.91x	0.34	0.00	0.01	0.33
CCW (kg)	5.15[b]	8.51[a]	9.76[a]	0.41	7.12[b]	8. 43x	0.33	0.00	0.01	0.33
CS (%)	5.80[a]	5.56[ab]	3.81[b]	0.57	4.36	5.70	0.47	0.038	>0.05	0.92
HCDP (%)	33.31[b]	40.12[a]	41.97[a]	1.07	39.00	37.90	0.87	0.00	0.33	0.58
CCDP (%)	31.41[b]	37.91[a]	40.37[a]	1.08	37.32	35.78	0.88	0.00	0.19	0.57
DPEB (%)	46.92	49.51	51.28[a]	1.40	49.49	49.00	1.14	0.09	0.73	0.05
REA (cm^2)	3.71[c]	5.34[b]	6.75[a]	0.31	4.81y	5.71x	0.26	0.00	0.00	0.49

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean.
[f]CCW=Cold carcass weight on SBW basis; CCDP=Cold carcass dressing percentage on SBW basis; CS=Chilling shrinkage; EBW=Empty body weight; DPEB=cold carcass dressing percentage on EBW basis; HCW=Hot carcass weight; HCDP=Hot carcass dressing percentage; SBW= Slaughter body weight; REA=Ribeye area;
[a,b,c]Meandiet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

solutions between each measurement. For color measurements, the cut surface of chilled samples was freshly exposed on flat surface of white background in the measuring room, and allowed to bloom for about 30 to 45 min at ambient temperature. Then, meat color parameters (CIE-values, lightness (L*), redness (a*) and yellowness (b*)) were obtained using a digital colorimeter (HunterLabMiniScan EZ, Serial No. MsEZ1547) calibrated with black and white standardized plates between measurements (AMSA 2012). For both pH and color three readings at different locations per sample were taken and averaged.

Proximate chemical analysis of meat

The determination of moisture, crude protein (CP), fat and ash was performed according to the methods described by the Association of Official Analytical Chemists (AOAC, 1995).

Sensory evaluation for eating quality of meat

Samples were randomly assigned for sensory evaluation by 8 semi-trained panellists according to AMSA (1995). The assessors were teaching staff members, laboratory technicians and post graduate students of food science and technology program of Haramaya University. The samples were tested for tenderness, juiciness, flavor and overall acceptability by rating on a 7 points hedonic scale. The thawed samples were cut into equal pieces, wrapped individually in aluminum foil and oven roasted at 125°C for 45 min (Griffin et al., 1985; as cited by Abdel et al., 2010). Immediately after roasting, the samples were cut into uniform size pieces and held in a food warmer until served. Before the analysis was made the order of service was decided by drawing the code of a sample from its group among the six breeds by diet groups randomly. The pieces of samples were served to the panelists at a time and only once so that every panelist evaluates samples from all lambs randomly. The analysis was done by the same panelists in two consecutive days (21 samples each) at the same time in the afternoon (2:00 to 5:00 pm). The data were reported by the assessors filling a form with pencil. The data were pooled over the panelists for individual lamb and the average of the 8 assessors for an attribute was taken as an observation for the lamb.

Statistical analysis

Data were analyzed using JMP™, The Statistical Discovery Software™ Version 5 and mean differences were tested using LSMean Tukey HSD mean separation tool (SAS, 2002) and considered significant at p<0.05. The model used for all carcass and meat quality variables as well as sensory attribute evaluation taking the panelists as block was:

$$Y_{ijk}= \mu + b_i + d_j + (bd)_{ij} + e_{ijk}$$

Where: $\mathbf{Y_{ij}}$= Response variable; $\boldsymbol{\mu}$ = mean of the population; $\mathbf{b_i}$ = the $\mathbf{i}^{th}$ breed effect; $\mathbf{d_j}$= j^{th}diet effect; $\mathbf{(bd)_{ij}}$= the effect of interaction between $\mathbf{i}^{th}$ breed and $\mathbf{j}^{th}$diet; $\mathbf{e_{ijk}}$**=** random error.

RESULT AND DISCUSSION

Carcass characteristics and yield

Table 2 presents the carcass characteristics and yield attribute of *AB* and *Af* lambs. The *AB* lambs showed higher (p< 0.05) SBW, EBW, HCW, CCW and REA than the *Af* lambs while breed did not affect (p>0.05) the CS, HCDP, CCDP and DPEB.

Similar to the present study, other studies reported that breed affects the carcass characteristics and yield traits (Flakemore et al., 2015; Kashan et al., 2005 and Macit et al., 2002). In his study where he used supplemented untreated TS basal diet, Getahun (2014) indicated superiority of *Af* over black head *Ogaden* (BHO) lambs in SBW, HCW and HCDP. The diets affected all parameters except DPEB. Both supplements were similar to each

Table 3. Morphmetric carcass measurements of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D1	D2	D3		Af	AB		T	B	T x B
CL (cm)	36.53[b]	41.39[ab]	41.94[a]	1.57	39.28	40.53	1.28	0.04	0.51	0.87
LL (cm)	27.36	27.86	27.74	0.42	26.23y	29.01[x]	0.35	0.74	<0.00	0.99
BW (cm)	25.12[b]	29.52[a]	29.84[a]	0.92	26.11y	30.05[x]	0.75	0.00	0.00	0.80
CW (cm)	10.36[b]	15.27[a]	15.50[a]	1.07	14.37	13.00	0.87	0.00	0.23	0.08
SW (cm)	16.89[b]	20.23[a]	21.34[a]	0.96	19.24	19.68	0.78	0.01	0.72	0.69
TC (cm)	51.34[b]	62.76[a]	60.04[ab]	2.80	55.32	60.42	2.29	0.02	0.14	0.84
ABC (cm)	37.6[b]	50.7[a]	49.0[a]	1.69	44.2	47.0	1.38	0.00	0.22	0.53
PBC (cm)	44.26[b]	53.34[a]	53.91[a]	0.95	48.16y	52.58[x]	0.78	0.00	0.00	0.79
LC	0.92[b]	1.06[a]	1.08[a]	0.04	1.00	1.04	0.03	0.01	0.46	0.74
CC (kg/cm)	0.14[b]	0.21[a]	0.23[a]	0.01	0.18[a]	0.20[a]	0.008	0.00	0.10	0.92

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean.
[f]CCW=Cold carcass weight on SBW basis; CCDP=Cold carcass dressing percentage on SBW basis; CS=Chilling shrinkage; EBW=Empty body weight; DPEB=cold carcass dressing percentage on EBW basis; HCW=Hot carcass weight; HCDP=Hot carcass dressing percentage; SBW= Slaughter body weight; REA=Ribeye area;
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

other except for REA, but improved (p<0.05) performance over the control. Chilling shrinkage was higher (p<0.05) in lambs fed control diet, the lowest being for D_3; implying the positive impact of supplementation. The REA was also improved (p<0.05) by supplementation, the higher being for lambs on D_3 followed by D_2 and D_1 groups. The lower CS and higher REA of the D_3 group may show the betterment of WBB and NSC mix than sole WBB supplementation for higher meat yield with minimum storage loss. Similarly, Tesfay and Solomon (2009) found improvement in SBW, EBW, HCW and REA on *Af* rams fed supplemented untreated TS. In his study that compare straws of five faba bean varieties supplemented with concentrate mix of untreated wheat bran and NSC fed to *AB* sheep *ad libitum,* Teklu (2016) found no different carcass characteristics, dressing percentage and REA except SBW and EBW. His report confirmed the lack of difference in carcass characteristics of this study, but opposed the REA result which could be due to the difference in the basal diets.

In another study where supplemented urea treated barley straw was used (*Abebe and Yoseph,* 2015***), AB*** sheep scored increasingly higher SBW, EBW, HCW and REA with increasing level of supplementation. Their results support the findings of the present study as all supplemented lambs were higher than the control on these parameters. *Melese et al. (2017)* also *confirmed the same trend of carcass traits improvement on* Washera *sheep due to supplementation of hay by concentrates.* According to Lloyd et al. (1981) and *Žgur et al.* (2003), higher values of carcass traits are apparent for heavier lambs. This is directly in support of the findings of the present study as all higher traits except CS (higher value implies lower quality) were of heavier lambs. The effects of interaction between breed and diet are not discussed, as they did not affect carcass characteristics and yield traits (Table 2). Similarly, other studies done on various sheep breeds and different treatment diets found no interaction effects (Getahun, 2014; Tsegay et al., 2012).

Carcass linear measurements

Table 3 summarizes morphometric carcass measurements. None of the measurements were affected (p>0.05) by breed, except LL and BW, which were higher (p<0.05) for *AB* lambs. In agreement with this study, Macit et al. (2002) and Popova and Marinova (2013) found no effect of breed on CL. They also found no difference between breeds on LL, as opposed to the present study. Concurring with the present study, two Ethiopian local sheep breeds and their cross with Dorper were found to be different for LL, BW and PBC measurements (Tsegay et al., 2012). The same authors also reported contrary result to the present study of different CL, ABC, TC, BW, SW and CW measurements and similar CC measurements. These differences in result might be attributed to the difference in the breeds and diets used in the experiments. Diet did not affect LL, while the supplemented groups were higher (p<0.05) than the control groups and similar to each other for BW, CW, SW, ABC, PBC, LC and CC. Yet, TC of D_2 and CL of D_3 lambs were higher (p<0.05) than the control lambs but similar to the other supplemented groups which were also not different (p>0.05) from the control groups.

Supporting the results of the present study Majdoub-Mathlouthi et al. (2013) who fed oat hay based diet

Table 4. Proportion (g kg^{-1}) of edible offal components to empty body weight of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
Blood	72.52	60.29	65.07	8.67	60.09	71.82	7.081	0. 60	0.24	0. 90
Heart	5.49	4.88	4.93	0.20	5.06	5.15	0.16	0.06	0.69	0.98
Kidney	3.80	3.53	3.47	0.13	3.60	3.60	0.10	0.14	0.92	0.18
Liver	15.13	17.34	16.00	0.73	15.94	16.31	0.59	0.12	0.71	0.77
ES	39.61	36.87	37.24	2.28	39.40	36.53	1.86	0.65	0.30	0.78
EI	40.32^{ab}	43.72^{a}	38.47^{b}	1.47	37.53^{y}	44.13^{x}	1.20	0.05	0.0004	0.11
Head	97.77^{a}	73.73^{b}	67.77^{b}	2.30	79.69	80.10	1.88	<0.0001	0.75	0.26
Tongue	4.84^{a}	4.65^{ab}	3.72^{b}	0.33	4.59	4.21	0.27	0.04	0.30	0.14
TF	23.63	34.20	38.44	5.30	42.17^{x}	22.38^{y}	4.33	0.126	0.002	0.80
HF	1.12	1.84	1.82	0.28	1.95^{x}	1.24^{y}	0.23	0.12	0.03	0.50
OF	5.55	5.09	6.88	0.75	6.03	5.64	0.61	0.23	0.65	0.84
MF	2.62^{b}	4.74^{ab}	6.79^{a}	0.71	5.00	4.43	0.58	0.001	0.49	0.29
TENCF	9.29^{b}	11.63^{ab}	15.48^{a}	1.11	13.02	11.31	0.91	0.001	0.20	0.93
TEO	239.96	231.04	225.59	5.93	241.07^{x}	223.79^{y}	4.84	0.23	0.02	0.56

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean.
[f]EI= Empty intestine; ES=Empty stomach; HF=Heart fat; MF= mesenteric fat; OF= Omentalfat; Means in columns in each effect categories superscribed by different letters are significantly different; TENCF= Total non edible carcass fat; TEO=Total Edible offal
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

supplemented with concentrate to weaned Barbarine lambs, reported that diet affected LC and CC, and did not affect LL and rump circumference. The same authors also found contradictory result of a no diet effect on CL. Likewise, Ahmed et al.(2012) reported no effect of diet on LL of *Af* sheep fed on Rhodes grass hay basal diet supplemented by *Prosopis juliflora* pods or/and leaves. In contrast, Tsegay et al. (2012) reported diet affected LL and did not affect CL, TC and SW. They also found similar results with the present study that diet effect was seen on PBC, ABC, BW, CW and CC. The breed x diet interaction effect was none (p>0.05) for all linear carcass measurements, except CC, for which all supplemented were similar to each other and higher (p<0.05) than the control lambs. However, the control *Af* lambs were not different (p>0.05) from *Af* lambs onD_2.Previous studies also observed no breed and diet interaction effects (Getahun, 2014; Tsegay et al., 2012).

Non-carcass components

Edible offal

Table 4 presents the proportion (g kg^{-1}) of edible offal components to empty body weight of *Arsi-Bale* and *Afar* lambs. The effect of interaction between breed and diet is not presented as it was not seen (p>0.05) for any of the components. Breed affected (p<0.05) only empty intestine (EI), tail fat (TF), heart fat (HF), total edible non carcass fat (TENCF) and total edible offal (TEO) for which the *Af* lambs were higher (p<0.05) than *AB* lambs except for the EI.

In agreement with the present study, Singh et al. (2003) reported breed effect on percentage of TEO. Further, Macit et al. (2002) reported no effect of breed on percentage of head, liver and heart which confirmed the result of the present study. In another study that compared hair and wool type breeds of Mexican sheep, no differences were found on proportion of head, blood and gastro-intestinal viscera (Hernández-Cruz et al., 2009). Their result is in line with the present study except that EI and empty stomach (ES) were reported in combination as gastro-intestinal viscera.

However, a contrary result of genotype affecting percentage of liver, heart and head was found by Cividini et al. (2012). In their study aimed to evaluate effect of days of rest before slaughter, Abebe et al. (2010) found no difference between *AB* and BHO sheep on percentage of head, heart and liver which is similar to the present study. Conversely, genotype was found affecting the same components in an experiment done on the same breeds with the aim of evaluating effect of length of feeding period before slaughter (Merera, 2010).

The proportion of EBW of blood, heart, kidney, liver and ES was affected by neither breed nor diet. The diet effect was found (p<0.05) only on EI, head, tongue, mesenteric fat (MF) and TENCF. Proportion of empty stomach (ES)

Table 5. Proportion (g kg^{-1}) of inedible offal components to empty body weight of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Variable[f]	Treatment (T)[e]			SEM[e]	Breed (B)[e]		SEM[e]	p-value		
	D_1	D_2	D_3		*Af*	*AB*		T	B	T x B
Lungs	13.68[a]	11.68[b]	10.89[b]	0.45	11.38[y]	12.77[x]	0.37	0.0003	0.01	0.13
Trachea	3.67	3.37	3.63	0.28	3.58	3.54	0.23	0.79	0.87	0.07
Oeso	2.63[a]	2.10[b]	1.98[b]	0.11	2.41[x]	2.07[y]	0.09	0.0003	0.01	0. 90
Spleen	1.94	3.15	2.69	0.23	2.79	2.38	0.19	0.002	0.09	0.33
Panc	1.77	1.35	1.50	0.13	1.58	1.51	0.11	0.09	0.71	0.51
UB	1.48	1.91	2.23	0.28	1.91	1.84	0.23	0.17	0.80	0.09
GB	0.55	0.91	0.97	0.18	0.96	0.67	0.15	0.22	0.18	0.96
Penis	2.85[a]	2.40[b]	2.31[b]	0.11	2.75[x]	2.30[y]	0.09	0.004	0.002	0.66
Testis	13.62	14.17	12.50	3.38	15.86	11.06	2.76	0.94	0.23	0.26
GF	1.77[b]	3.35[a]	3.17[a]	0.31	3.54[x]	1.99[y]	0.25	0.001	<0.0001	0.06
KF	1.77[b]	2.24[b]	3.17[a]	0.23	2.45	2.34	0.18	0.0002	0.68	0.35
Feet	35.89[a]	29.22[b]	26.92[b]	0.86	31.38	30.05	0.70	<0.0001	0.22	0.84
Skin	134.93	137.77	129.73	6.87	132.89	135.16	5.61	0.71	0.801	0.45
TNEO	628.26[a]	448.15[b]	423.09[b]	20.81	485.95	516.02	17.00	<0.0001	0.19	0.72

[e]AB =AB lambs; Af=Afar lambs; D1=Sole tef straw silage; D2= tef straw silage supplemented with WBB alone; D3= tef straw silage supplemented with mix of WBB and NSC; SEM=Standard error of mean. f GB=Gall bladder; GF=Genital fat; KF=kidney fat; Oeso=Oesophagus; Panc=Pancreas UB=Urinary bladder; TNEO=Total inedible offal.
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

was higher ($p<0.05$) in D_2 lambs compared to that of D_3 while D_1 lambs were similar ($p>0.05$) to both groups. The proportion of head of the control lambs was higher ($p<0.05$) than the supplemented lambs which were not different ($p>0.05$) from each other. The control labs had higher ($p>0.05$) proportion of tongue than lambs on D_3 while that of D_2 were not statistically ($p>0.05$) different from both diet groups. The MF and TENCF were found in higher ($p>0.05$) proportion in the D_3 lambs compared to the control lambs while that of D_2 lambs was similar ($p>0.05$) to both groups.

Confirming the present study, Majdoub-Mathlouthi et al. (2013) reported diet affecting proportion of empty gut and not affecting proportion of heart. The same authors also reported a contradictory result to the present study that they found effect of diet on proportion of liver and kidney. However, similar to this study, none diet effect on percentage of TEO was reported (Singh et al., 2003). The reason for the variation seen could be due to the difference in the experimental diet and the genotype of the experimental lambs.

None edible offal

The proportion (g kg^{-1}) of inedible offal components to empty body weight of *AB* and *Af* lambs is presented in Table 5. The breed x diet interaction effect was not seen ($p>0.05$) on any of the components and hence not presented. The proportions to the EBWof lungs, oesophagus (Oeso), penis and genital fat (GF) were affected by breed for which *Af* lambs were higher ($p<0.05$) than the *AB* lambs. Trachea, spleen, pancreas, urinary bladder (UB), gall bladder (GB), testis, kidney fat (KF), feet, skin and total non- edible offal (TNEO) were not affected ($p>0.05$) by breed.

Supporting the result of this study, genotype was reported to have effect on percentage of lungs (Cividini et al., 2012). In contrast to the present study, the same authors found that genotype affected percentage of spleen and skin. However, Singh et al. (2003) reported no effect of breed on percentage of TNEO confirming the results of the present study. Hair and wool type sheep comparison revealed effect on skin and no effect on feet percentage (Hernández-Cruz et al., 2009), which is in disagreement with the present study. Similar to the present study, Macit et al. (2002) found no differences between three sheep breeds on proportion of spleen, testis, feet and skin. However, in contrast to this study, they also found no difference on the proportion of lungs. In contrast to the present study, in an experiment investigating the effect of days of rest before slaughter, *AB* and BHO sheep were reported as different on percentage of spleen and skin (Abebe et al., 2010). As the same time, in support of this study, they also found testis not affected by breed. On the other hand, Merera et al. (2010), in their study examining the impact of length of feeding period before slaughter, revealed a contrasting result of difference between the two sheep breeds on percentage of skin and similar result of no variation on

Table 6. Least square mean physicochemical characteristics and chemical composition of meat (*Longismus dorsi* muscle) of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Treatment (T)[e]	D_1		D_2		D_3		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
BDL (%)[f]	13.45	12.66	11.42	8.81	11.28	11.04	1.25	0.07	0.25	0.63
pH[f]										
pH_{45}	6.30	6.34	6.40	6.13	6.34	6.29	1.13	0.91	0.36	0.49
pH_{24}	5.66^{a}	6.19^{a}	5.65^{ab}	5.55^{ab}	5.20^{b}	5.46^{b}	0.22	0.00	0.33	0.79
Color[f]										
L*	32.86^{b}	28.76^{b}	32.28^{ab}	34.98^{ab}	37.03^{a}	34.00^{a}	1.54	0.01	0.25	0.08
a*	12.77	14.08	15.89	13.72	14.18	14.80	0.75	0.17	0.90	0.07
b*	14.80	13.86	14.81	14.33	14.92	14.28	0.41	0.76	0.047	0.85
Moisture (%) and proximate chemical composition (%DM)[f]										
Moisture	72.81^{a}	73.50^{a}	72.20^{ab}	72.75^{ab}	71.72^{b}	71.28^{b}	0.50	0.01	0.52	0.47
CP	20.65	21.65	21.01	20.01	20.12	20.40	0.44	0.12	0.78	0.09
Ash	4.89^{a}	4.84^{a}	4.44^{ab}	4.53^{ab}	4.33^{b}	4.19^{b}	0.18	0.01	0.83	0.84
Fat	6.35^{cx}	3.66^{cy}	9.19^{bx}	8.97^{by}	11.83^{ax}	9.97^{ay}	0.48	0.00	0.00	0.02

[e]Af=Afar Breed; AB=Arsi-Bale Breed; D1=Sole fermented TS; D2 =Fermented TS supplemented with WBB alone; D3=Fermented TS supplemented with mix of WBB and NSC; SEM.=standard error of mean; TS=Tef straw; Values in a row superscribed by different letters are significantly different, letters a,b,c standing for diet and x,y,z standing for breed.
[f]BDL = Bag drip loss; L* Measure Lightness and varies from 100 for perfect white to zero for black, a* measure redness when +ve, grey when zero, green when -ve, b* measure yellowness when +ve, grey when zero, blue when -ve ; pH45 = pH measure taken 45 min after flaying; pH24 = pH measure taken after 24 h chilling; CP = Crude protein;
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; x,y Mean breed effects in a row superscribed by different letters are significantly different.

feet and testis percentages. The proportion to the EBW of trachea, spleen, pancreas, UB, GB, testis and skin was not affected ($p>0.05$) by diet. The proportions of lungs, oesophagus, penis, feet and TNEO were higher ($p<0.05$) for the control diet lambs than both supplemented groups which were not different ($p>0.05$) from each other. The supplemented lambs scored similar ($p>0.05$) to each other but higher ($p<0.05$) proportion of genital fat (GF) over the control group while proportion of kidney fat (KF) of lambs on D3 was higher ($p<0.05$) than the control and D2 groups which were not different ($p>0.05$) from each other.

Contrary to this study, Singh et al. (2003) found similar percentage of TNEO among lambs fed different rations. Majdoub-Mathlouthi et al. (2013) also reported a contradicting result of percentage of testis affected by diet.

Physicochemical characteristics and chemical composition of meat

The physicochemical characteristics and chemical composition of the meat (*Longismus dorsi* muscle) are presented in Table 6. The BDL, pH_{45} and a* color measures were not affected by breed or diet. Breed affected only the b*color measure and fat content being higher ($p = 0.05$) for *Af* than for *AB* lambs. Diet affected pH_{24} and L* color measure.

Hopkins and Fogarty (1998) found no effect of genotype on pH and color of six genotypes they studied except a pH difference seen among ewes only. Hernández-Cruz et al. (2009) also reported a similar lack of effect of genotype on loin meat color of hair and wool type sheep and *Çelik and Yilmaz (2010) reported no difference between Awassi and their cross with Turkish Merino on meat* $pH_{45\&24}$. Their results confirm the results of the present study with the exception of yellowness, for which meat from *Af* lambs was more ($p<0.05$) yellow. Contradicting the result of the present study, Blackhead Persian, Dorper and South African mutton Merino were noted with different meat pH_{24} and color (except the a*) values (Chulayo and Muchenje, 2013), while Martínez-Cerezo et al. (2005) found differences in color values between three breeds. Abebe et al. (2010) reported pH_{24} and color (except lightness) variability between *AB* and BHO lambs. This result divergence could be attributed to the differences in the breeds and management of the experimental animals and different experimental treatments applied.

Regarding diet effects, the pH_{24} was found higher ($p<0.05$) for control diet compared to D_3, while D_2 was not different ($p<0.05$) from both control and D_3. The lightness (L*) was lower ($p<0.05$) in control diet than in D_3 while D_2 was not different ($p<0.05$) from both control and D_3. None of the physicochemical traits were affected by an

Table 7. Least square mean ranking (on 7 points hedonic scale) of sensory eating quality of meat (Longismuss dorsi muscle) of Arsi-Bale and Afar lambs fed on sole TSS or supplemented with WBB or concentrate mix.

Treatment (T)[e]	D_1		D_2		D_3		SEM[e]	p-value		
Breed (B)[e]	*Af*	*AB*	*Af*	*AB*	*Af*	*AB*		T	B	T x B
Tenderness	4.07^{b}	3.97^{b}	5.69^{a}	5.25^{a}	6.18^{a}	5.50^{a}	0.32	0.00	0.13	0.66
Juiciness	3.63^{b}	4.17^{b}	5.13^{a}	4.98^{a}	5.04^{a}	5.25^{a}	0.26	0.00	0.35	0.45
Flavor	3.90^{b}	4.38^{b}	5.57^{a}	5.02^{a}	5.66^{a}	5.41^{a}	0.24	0.00	0.59	0.09
GenrAccep[f]	3.48^{bs}	4.20^{brs}	5.79^{aq}	5.13^{aqr}	5.93^{aq}	5.54^{aq}	0.23	0.00	0.54	0.01

[e]Af=Afar Breed; AB=Arsi-Bale Breed; D1=Sole fermented TS; D2 =Fermented TS supplemented with WBB alone; D3=Fermented TS supplemented with mix of WBB and NSC; SEM.=standard error of mean; TS=Tef straw; fGenrAccep= General Acceptability.
[a,b,c]Mean diet effects in a row superscribed by different letters are significantly different; q,r,s Mean breed x diet interaction effects in a row superscribed by different letters are significantly different;x,y Mean breed effects in a row superscribed by different letters are significantly different.

interaction between breed and diet and hence not discussed.

Color and pH taken at 1 and 24 h post mortem of *Longismus dorsi* meat of *Washera* and Afar sheep were not influenced by level of supplementation and types of feed (Melese et al., 2017; Ahmed et al., 2012). Likewise, Sheridan et al. (2003) reported no effect of diet on color of 8-9-10-rib cut meat of mutton Merino lambs. The result of the present study is in agreement with their result, but pH_{24} and L* color value. With the exception of *AB* lambs on the control diet and *Af* lambs on D_3, the physicochemical values generally fall in the ranges (5.4-5.8 pH_{24}, ≥34 L* and ≥ 9.5 a* values) considered as normal (Chulayo and Muchenje, 2013; Dragomir, 2005, as cited by Majdoub-Mathlouthi et al. (2013); Khliji et al. (2010) and MSA (2015). Generally lambs with heavier SBW exhibited lower pH_{24} and lighter (L*) color (Table 2 and Table 6) confirming the result reported by Majdoub-Mathlouthi et al. (2013).

Chemical composition was not affected by breed except fat content, which was also affected by diet and the interaction as well, whereas moisture and ash contents were affected by diet only. The CP content was not influenced by either of the effects. The moisture and ash contents of the meat from lambs fed the control diet were higher (p>0.05) than those of lambs on D_3 while lambs on D_2 were in between with no variation from both. In contrast, the fat content was higher (p<0.05) in meat from the lambs fed supplemented diets than those on control, *Af* lambs onD_3 being the highest (p< 0.05) followed by *AB*lambs on D_3 which in turn was not different from *Af* lambs onD_2. The fat content of samples from *Af* lambs on the control diet was also higher (p< 0.05) than that of *AB* lambs given the same diet. This may lead to the generalization that *Af* lambs were more fatty than the *AB* lambs. This conclusion is confirmed by the fact that *Af* sheep breed was categorized as a breed of fatty carcass (Gizaw, 2009).

Lambs of *Pelibuey* and *Polypay*x *Rambouillet* were compared and found not different on proximate chemical composition of the *L. dorsi* muscle (Peraza-Mercado et al., 2010). This finding is in line with the present study except for fat which was influenced by breed. Substantiating the result of the present study, Abd El-aal and Suliman (2008) reported differences between the diet groups on proximate chemical composition of meat from *L. dorsi* muscle of sheep. The lower fat concentration of meat produced from lambs on the control diet could be associated with their higher moisture content. This is best explained by the inverse relationship that exists between fat and moisture concentrations of carcasses (Stankov et al., 2002).

The sensory eating quality of meat

The sensory eating quality of meat of *AB* and *Af* lambs is summarized in Table 7. The breed of the lambs did not affect any attribute of the sensory eating qualities. Confirming the present finding, Hoffman et al. (2003) reported no effect of genotype on the sensory quality characteristics of *M. semimembranosus* muscle. From their review on factors affecting meat quality traits, Guerrero et al. (2013) found inconsistency among various research works on effect of genotypes on sensory eating quality as some found no effect and others reported large variability between breeds. Yet, they drew a generalization stating that the effect of breed on instrumental and sensory meat quality, such as pH, color, texture and sensory characteristics, is slight, most differences being probably due to differences in maturity or in muscularity levels.

In the present study, however, all the eating quality attributes were higher (p<0.05) for meat from the supplemented over the control lambs though they were not different from each other. The control lambs of both breeds were also not different (p>0.05) from each other for all attributes of meat sensory eating quality evaluated. Nevertheless, the meat samples from *Af* lambs on D_1 were less (p>0.05) tender than that of supplemented *Af* lambs but not different from the other lambs.

The juiciness, flavor and general acceptability were all higher (p>0.05) for the supplemented lambs of both breeds compared to the control *Af* lambs but not different from the control *AB* lambs.

Contrasting the present study, Panea et al. (2011) reported that feed type did not affect sensory characteristics of lamb. Similarly, Sheridan et al. (2003) also did not get any impact of diet on eating quality of meat from Mutton Merino lambs supplemented by either low or high energy concentrates. According to Beriain et al. (2000), there is little variation in toughness in lamb meat, if the management of cooling after slaughter is correct. Nevertheless, there are also other works that reported diet affecting the sensory attributes of meat (Mavimbela et al., 2000; Abd El-aal and Suliman, 2008).

Regardless of the statistical variability, all the supplemented lambs were distinguished as very good meat producers as all evaluated eating quality traits were ranked above five on seven point hedonic scale, the *Af* lambs scoring better value.

Conclusion

Except chilling loss and the dressing percentages for which both breeds were similar, the *Arsi-Bale* lambs were better than the *Afar* lambs in all the carcass characteristics that were also improved by supplementation. Most of the carcass linear measurements were influenced only by diet for which the supplemented lambs performed similar and better than the control. The affected proportion to empty body weight of non -carcass components was higher for *Afar* lambs and found lower for supplemented lambs.

The physicochemical characteristics and chemical composition of meat were similar for both breeds except L*color value and fat content which was higher for *Afar* lambs. As influenced by diet, control lambs scored higher pH_{24}, moisture and ash; and lower L*and fat. All the pH and color scores were in the acceptable standard ranges. All the evaluated sensory eating quality traits were similar and ranked as very good for both breeds' supplemented lambs.

Generally, compared to the *Afar*, the *Arsi-Bale* lambs can produce similar quality but better lean meat yield under the conditions of the present study. Yet, other meat yield and quality parameters not covered by this study such as length of feedlot time required for fulfilling export weight, amino and fatty acid profile and stability of physicochemical characteristics, technological meat quality need to be addressed in future studies.

ETHICS APPROVAL

This study was approved by the Animal Research Ethical Review Committee of College of Veterinary Medicine and Agriculture, Addis Ababa University, responsible for both animal and human ethical concerns:

(1) The feeding trial and slaughter of the animals were done in such a way that welfare of the lambs is fully maintained

(2) The sensory analysis of the meat sample was done by well aware and willing semi trained food science professionals after they get refresher training on meat sensory analysis which made them know the objective of the study, the way the meat samples were collected and stored until tested.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Genetic evaluation of dairy cattle based on morning and afternoon milking test day records with fixed regression model

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This study evaluated morning and afternoon test day records for genetic evaluation of dairy cattle. The data were taken form 128,087 test day yield records for the first four lactations of Holstein cows from 2007 to 2017, from Nucleus Breeding Center of dairy cattle in Indonesia. The records consisted of morning and afternoon and total milk yields from 823 cows, resulting from 133 sires and 520 dams; records were restricted to Day Interval Milk (DIM) between 5 and 305 days production. The genetic parameters were estimated with REML by using animal model with fixed regression. Ali and Schaeffer has a good fit for morning, afternoon and total test day yields with the coefficient of determination ranging from 0.980 to 0.995. Estimates of heritability were 0.177, 0.220, and 0.213 for morning, afternoon, and total test day records, respectively. Spearman rank correlations of breeding values between total yield and morning and afternoon yields, for both animals and sires, ranged between 0.953 and 0.968. In conclusion, morning and afternoon yields can be used for genetic evaluation of dairy cattle.

Key words: Genetic parameters, heritability, morning and afternoon yields, fixed regression model, dairy cattle.

INTRODUCTION

Genetic evaluation of milk yield in dairy cattle has now turned to the use of test day records. With this method, the yield is tested and recorded at certain interval time; for instance every week, every two weeks, every month, etc. The use of test day record is cheaper and more flexible than that of cumulative 305 day records, because the yield is not measured and tested every day, and the data are not adjusted to lactation length.

There are two ways to analyze test day records; (1) records treated as different traits with multivariate, and (2) records treated as the same traits with repeated measurements. Repeated measurement models are more popular than multivariate model (Swalve, 2000), and have been widely used for genetic evaluation of milk yield in many countries. Repeated measurement models were firstly introduced by Ptak and Schaeffer (1993) for fixed regression model, and Schaeffer and Dekkers (1994) and Jamrozik et al. (1997a) for random regression model. Both Ptak and Schaeffer (1993) and Jamrozik et al. (1997b) used regression curve, derived by Ali and Schaeffer (1987), and fitted as covariates. Fixed regression was a superior model for genetic evaluation

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Table 1. Data description.

Lactation	n	Yield	Mean (liter)	StDev
1	53,850	Morning	7.31	3.36
		Afternoon	6.49	2.88
		Total	13.80	5.92
2	25,488	Morning	7.80	2.97
		Afternoon	6.57	2.61
		Total	14.37	5.29
3	38,823	Morning	7.76	3.19
		Afternoon	6.76	2.85
		Total	14.51	5.65
4	9,926	Morning	8.77	3.48
		Afternoon	8.25	3.42
		Total	17.01	6.65

n = number of observation, StDev = Standard Deviation.

dairy cattle (Anang et al., 2001a; Indrijani and Anang, 2009) and sufficient for standard genetic evaluation (Liu at al., 2000), as in cases that the random regression might be biased up ward due to insufficient records (Anang et al., 2001b; Anang et al., 2002).

In many countries, milking is conducted twice a day; in which in early morning and afternoon. There is possibility to evaluate the animals based on morning or afternoon yields of test day record, to have the data collection cheaper and in where the recording is difficult to obtain, such as where the evaluation is conducted in small holder farmers. The purpose of this paper is to study the possible use of morning and afternoon for genetic evaluation of milk production in dairy cows.

MATERIALS AND METHODS

The data comprised 128,087 test day yield records for the first four lactation of Holstein cows from 2007 to 2017, taken at Nucleus Breeding Center of dairy cattle in Baturraden, Central Java Indonesia. The records consisted of morning and afternoon milk yield for each individual cow. The morning yield was milked at 4 am, while the afternoon production was milked at 4 pm. Total production was the additional morning and afternoon yields. 823 cows from 133 sires and 520 dams were evaluated, and the records were restricted to Day Interval Milk (DIM) between 5 to 305 days production. The data description is presented in Table 1.

Regression of Ali and Schaeffer (1987) fitted the data to evaluate the accuracy before estimating genetic parameters. The regression of Ali and Schaeffer is as follows:

$$y = a + b\left(\frac{DIM}{305}\right) + c\left(\frac{DIM}{305}\right)^2 + d\left(\ln\frac{305}{DIM}\right) + f\left(\ln\frac{305}{DIM}\right)^2$$

Where, y = test day yields (morning, afternoon, and total) in liter; *DIM* = Day Interval Milk (5 to 305 day)
a,b,c,d,and f = coefficients of regression

The accuracy was indicated with coefficient of determination (R^2) and standard error of prediction (se) and the calculation using proc nonlin within SAS 9.0. (SAS, 2002).
Genetic parameters were predicted with Restricted Maximum Likelihood (REML) with fixed regression model. The model is as follows:

$$y_{ijkl} = YS_i + L_l + \sum_{m=1}^{4} b_{lm}x_m + a_j + pe_j + e_{ijkl}$$

Where, y_{ijkl} = Test day yields (morning, afternoon, and total), YS_i= Year-Season (Year from 2007 to 2017, season was rain and dry) and L_l= Lactation (1 to 4)

$\sum_{m=1}^{4} b_{lm}x_m$ = four covariates from regression of Ali and Schaeffer (1987) and nested within lactation

Where, x_1= *DIM/305,* x_2 = $(DIM/305)^2$, x_3 = *ln(305/DIM)*, and x_4 = $\ln^2(305/DIM)$
a_j = additive genetic effect; pe_j = permanent environmental effect; e_{ijkl} = residual

The genetic parameters were estimated with VCE 6 (Groeneveld et al., 2010) and breeding values were predicted with PEST (Groeneveld, 1999). In addition, Spearman correlation of breeding values for animals and sires were estimated with proc corr within SAS 9.0. (SAS, 2002)

RESULTS AND DISCUSSION

Fitting regression of Ali and Schaeffer

Parameters of regression, R^2 and *se* by fitting regression of Ali and Schaeffer are presented in Table 2 and Figure 1. The coefficients of determination (R^2) ranged from 0.980 to 0.995, while the standard errors of prediction

Table 2. Regression Parameters, Coefficients of Determination (R^2), and Standard Errors of Prediction (*se*).

Parameters	First Lactation			Second Lactation			Third Lactation			Fourth Lactation		
	Morning	Afternoon	Total	Morning	Afternoon	Total	Morning	Afternoon	Total	Morning	Afternoon	Total
a	-7.096	-6.314	-13.417	18.826	13.144	31.990	2.985	4.294	7.246	-4.260	-10.788	-15.064
b	14.217	12.787	27.019	-26.106	-17.518	-43.635	2.305	-1.138	1.220	12.682	23.541	36.243
c	-1.614	-1.519	-3.141	13.772	10.278	24.031	-0.149	1.165	0.994	-1.995	-7.064	-9.063
d	11.143	9.786	20.932	-3.149	-1.009	-4.175	5.422	3.517	8.958	10.540	13.613	24.164
f	-1.847	-1.597	-3.443	0.116	-0.124	-0.004	-1.031	-0.671	-1.705	-1.873	-2.286	-4.160
R^2	0.992	0.993	0.995	0.993	0.993	0.995	0.994	0.995	0.996	0.980	0.980	0.984
se	0.142	0.124	0.211	0.101	0.085	0.157	0.130	0.099	0.205	0.227	0.218	0.390

ranged between 0.099 and 0.390 liter. High R^2 indicated that regression of Ali and Schaeffer has a good fit for morning, afternoon, and total yields. The computations of lactation curve for genetic evaluation have been conducted by Ali and Schaeffer (1987) (Jamrozik et al., 1997a; Indrijani et al., 2011). The results showed that regression of Ali and Schaeffer resulted in the best fit for genetic evaluation of dairy cattle with test day records.

Figure 1 shows that the yields increased from day 5 to reach the peak at day 35 and then decreased gradually. Morning yield was higher than afternoon yield. The results are in the line with the studies of Everet and Wandel (1970) and Gilbert et al. (1973). The reason might due to environmental factors, such as temperature, activities of the cows, ruminal processes.

Genetic parameters

Variance components, including estimate of additive genetic (Va), permanent environmental (Vp), residual (Ve) variances and estimates of heritability are presented in Table 3.

The estimates of heritability were 0.177, 0.220, and 0.213 for morning, afternoon, and total test day records, respectively. The estimate of heritability at afternoon was higher than morning yield. The estimate of heritability for total yield with fixed regression model was in the line with those estimated by Reents et al. (1995) using Gibbs Sampling, Swalve (1995), Strabel and Swaczkowski (1997), and Indrijani and Anang (2009) as well as REML. However, there was no study in estimating heritability based on morning and afternoon yield. Moderate heritabilities indicated that genetic evaluation based on test day records will result in good response for genetic evaluation of milk yield in dairy cattle.

Correlations of breeding values

Spearman correlation of breeding values between morning, afternoon, and total yield for all animals and sire are presented in Table 4.

There were high correlations of breeding values between total yield with morning and afternoon yield, for both animals and sire, ranging between 0.953 and 0.968.

The correlations between morning and afternoon yields were lower, 0.874 and 0.855 for both animal and sire, respectively. High correlation of breeding values between total production indicated that genetic evaluation of dairy cattle can be conducted based on morning or afternoon records as alternative of total record.

Conclusion

Regression Ali and Schaeffer has a good fit for morning, afternoon and total test day yields with the coefficient of determination ranging from 0.980 to 0.995. Estimate of heritabilites was generally moderate with 0.177, 0.220, and 0.213 for morning, afternoon, and total test day records, respectively. Spearman rank correlations of breeding values between total yield with morning and afternoon yields, for both animals and sires, ranging between 0.953 and 0.968. High correlation indicated that genetic evaluation of dairy cattle can be conducted based on morning or afternoon records as alternative of total record.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

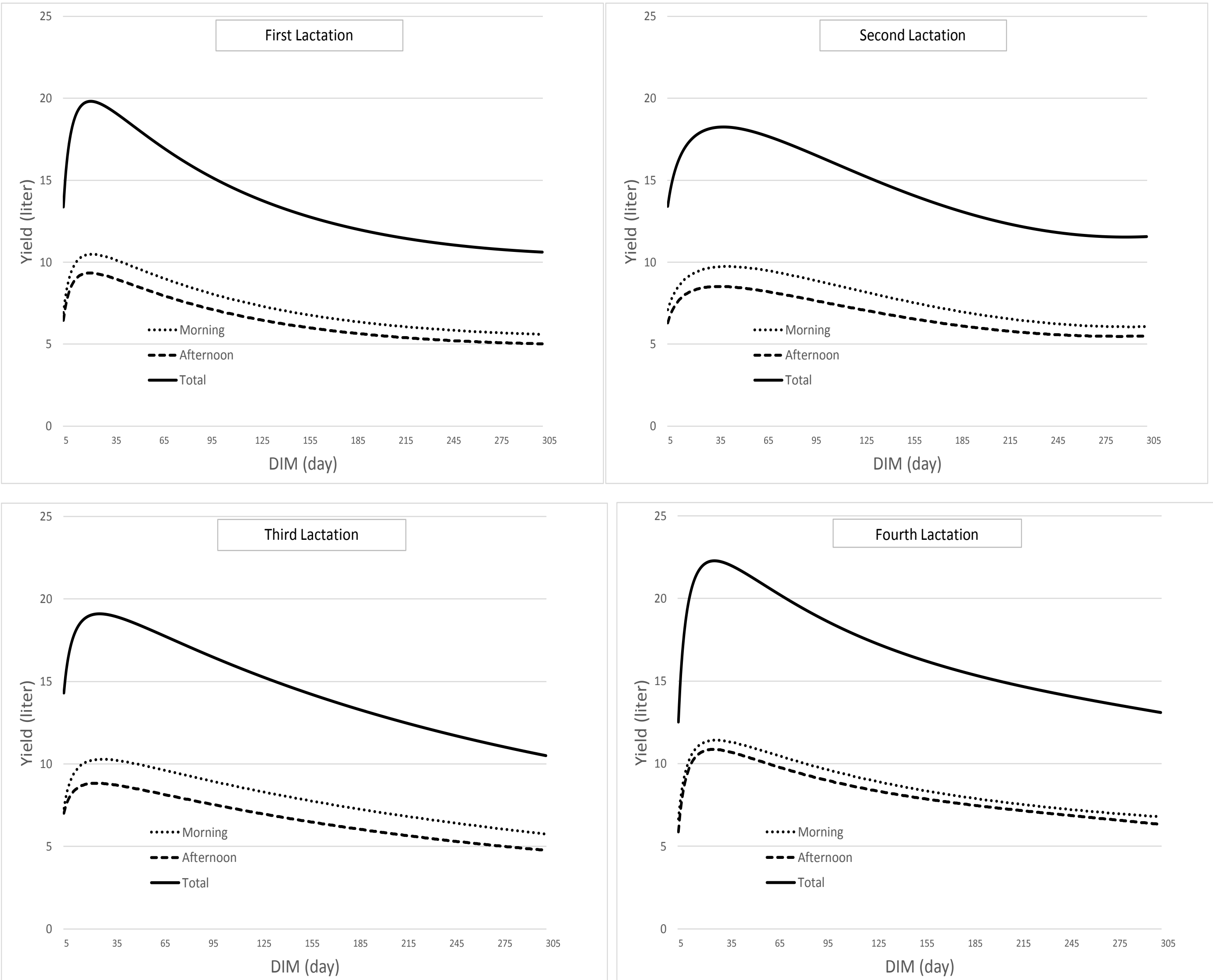

Figure 1. Lactation curves by fitting regression of Ali and Schaeffer (1987).

Table 3. Variance components.

Variance Components	*Va*	*Vp*	*Ve*	*h^2 (se)*
Morning	2.020	1.905	7.505	0.177 (0.006)
Afternoon	1.933	1.071	5.795	0.220 (0.039)
Total	8.178	6.069	24.133	0.213 (0.050)

Table 4. Spearman correlations of breeding values.

Parameter	Animal	Sire
Morning and Total	0.968	0.964
Afternoon and Total	0.959	0.953
Morning and Afternoon	0.874	0.855

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Genotype and sex effects on the performance characteristics of pigs

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Data from fifty-four pigs: twenty-five Duroc, twenty-one Large White and eight crosses of Duroc and Large White (Hybrid) were used to quantify and mathematically describe the performance traits of pigs. The aim of this study was to investigate the effects of genotype, sex and their interaction on the performance characteristics of three pig genotypes. The pigs were 30 kg of body weight and 70 days of age at the beginning of the study. Records for body weight (BW), body length (BL), feed intake (FI), feed conversion ratio (FCR), rump and back fat thickness, trunk length(TRL), height at withers (HW), chest girth (CG),tail length (TL), shoulder to tail length (STL) were used for the analysis. The results of the least squares means analysis on the performance traits showed that genotype and sex were important sources of variation for traits such as feed intake (FI), feed conversion ratio (FCR), rump and back fat thickness. Also, the linear body traits namely; body weight (BW), body length (BL), trunk length (TRL), height at withers (HW), chest girth (CG), tail length(TL) and shoulder to tail length (STL) were significantly (P<0.05) influenced by genotype and sex. The male sex and the hybrid had better performance traits at various stages.

Key words: Pig, genotype, sex, hybrid, duroc, Large White.

INTRODUCTION

Genotype, sex and genotype-sex interaction (G×S) is increasingly important, because breeding programs depends on the selection of good genotype and the sex through which the effort will be concentrated for the propagation of the next generation. The main objective of the production of slaughter pigs is undoubtedly profit which is a function of the whole complex of characters, that is, qualities characterizing reproduction and production traits. Production traits in farm animals are the resultant of an additive effect of the genes. The quantitative qualities are influenced by the genotype and environment. As a result, production traits may be improved both by genetic and non-genetic measures (Sprysl et al., 2005).

In pig production, selection is performed in purebred lines and the final product is a crossbred animal; also, there is an anticipated benefit of using crossbred information for estimating breeding values of purebred for crossbred performance (Hidalgo et al., 2015; Lopes et al., 2017).

The choice of a suitable genotype for the particular conditions of commercial breeding is a decisive step for pig breeders. Performance and suitability of various genotypes are verified by tests of populations.

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Most important traits have an economic and a noneconomic value and are sufficiently heritable for effective genetic selection (Kanis et al., 2005). The phenotypic value (P) of an individual is the combined effect of the genotypic value (G) and the environmental deviation (E): P = G + E, while the genotypic value is the combined effect of all the genetic effects, including nuclear genes, mitochondrial genes and interactions between the genes (Knap et al., 2003).

Nevertheless, Whittemore and Green (2001) worked on the use of Gompertz growth function to describe the potential growth rate in pigs, which animals desire to achieve. Moreover, there have not been many studies on the effects of genotype, sex and their interaction on the growth and carcass characteristics of different pig genotypes in the humid tropics. Linear body measurements provide good information on performance, productivity and carcass characteristics of animals (Ige et al*.,* 2006). So many researchers had used linear body measurements to predict performance characteristics in poultry (Oni et al*.,* 2001; Adenowo and Omoniyi, 2004), goats (Ozoje and Mbere, 2002), sheep (Salako and Ngere, 2002; Salako, 2004) and cattle (Mbap and Bawa, 2001; Olutogun et al*.,* 2003). However, there is a paucity of reported work on the use of linear body measurements as tools for pig improvement in Nigeria (Egena, 2010). Hence, the findings from this study will serve as complementary information to pig improvement and production.

MATERIALS AND METHODS

The experiment was carried out at the Piggery Unit of the Teaching and Research Farm, Federal University of Technology, Akure, Nigeria. A total of 240 pigs of three genotypes: Duroc (DU), Large White (LW) and Hybrid (HY); averaging 30 kg weight at the time of the trial were used to conduct the experiment. The animals were sourced from the Livestock Department of the Ministry of Agriculture and Natural Resources, Ondo, Ondo State, Nigeria. They were allotted into clean pens, and feed and water were supplied regularly. The weights of the animal and linear measurements were taken on weekly basis while the feed intake was taken daily. The composition of the experimental diet is presented in Table 1. The diet satisfied the nutrient requirements of the animals at the various physiological phases as recommended by NRC (1998).

Statistical analysis

Data generated from the trial were subjected to analyses of variance using SAS (version 9.2). The effects of genotype, sex and genotype-sex interaction on body weight at 21, 35 and 56 days of the trial were estimated from least squares procedures of unequal sub-class numbers (SAS, 2008). Where significant differences were observed, differences between means were tested using Duncan's multiple range test outlined in the SAS statistical package. The factors were defined as shown:

Genotypes: Duroc (DU), Large White (LW) and Hybrid (HY)
Sex: Male and female.

The models used for individual weight at 21, 35 and 56 days of age were:

$$Y_{ijk} = U + B_i + C_j + (BC)_{ij} + E_{ijk}$$

where Y_{ijk} = the observation of the dependent variable on the $_i^{th}$ genotype and the $_j^{th}$ sex of the pigs.
U = overall mean of all observations; B_i = effect of the genotype of pig, i = 1, 2, 3, (DU, LW and HY)
C_j = effect of the $_j^{th}$ sex of pig; $_j$ = 1, 2 (male, female); $(BC)_{ij}$ = effect of interaction between i^{th} genotype of pig and $_j^{th}$ sex of pig; E_{ijk} = random error.

Linear body measurement

The body weight was obtained preferably in the morning before feeding the pigs. The pigs were restrained in a sack attached to a hanging scale. All linear measurements and weights were recorded. Live weight (kg) which is the actual body weight of the animals was obtained using livestock scale. Body length (cm) was taken from the base of the ear to the base of the tail. The heart or chest girth (cm) was recorded at the chest area just behind the forelegs. The initial body weights of the pigs were taken on day 1 of the trial and subsequently on weekly basis. Feed intake record was taken on daily basis. Feed conversion ratio was calculated as ratio of feed/gain. Measurements of chest girth (cm), scrotal size, rump depth, trunk length, tail length, back fat thickness, shoulder to tail, height at withers (cm) and body length were taken as earlier described by Onyimonyi (2002).

RESULTS

The estimated least-squares means of performance characteristics and linear body measurements by genotype and sex for days 35 and 56 of the experiment are presented in Tables 2 to 6.

The least squares means of analyses of variance for performance characteristics at 35 days of the experiment namely; body weight, feed intake, feed conversion ratio, rump, teat number and scrotal size are shown in Table 2. Genotype differs significantly (P<0.05) for body weight, feed intake and feed conversion ratio. The Hybrid showed the best performance among the three genotypes for body weight, feed intake, feed and rump depth with the following means 44.11±1.83 kg, 12.78±0.46 kg and 52.28±2.10 cm accordingly. Duroc showed the best performance for feed conversion ratio (5.05±1.37). Sex significantly (P<0.05) influenced feed intake where the female recorded the highest means (12.44±0.58 kg) and the male sex recorded the lowest means (9.72±1.15 kg). Genotype-sex interaction was not significantly different (P<0.05) for all parameters on performance characteristics at 35 days of the study.

Least squares means of performance characteristic at 56 days is shown in Table 3. Genotype was a major source of variation where the highest means for body weight, feed intake, feed conversion ratio and rump depth which were observed for Hybrid (HY): 67.61±4.87 kg, 13.06±1.14 kg, 4.20±0.25 and 51.41±1.22 cm respectively; Duroc had the highest means for scrotal

Table 1. Dietary composition of feed (g/100g) for the experimental pigs.

Ingredient	Composition (%)
Maize	35.25
GNC	16.75
PKC	25.00
Cassava peel	20.00
Bone meal	1.50
Oyster shell	0.50
Vitamin premix	0.50
Salt	0.50
Total	100.00
Calculated composition	
C.P (%)	18.03
ME (kcal/kg)	2900.30
C.F (%)	6.35

Table 2. Least squares means for performance characteristics at 35days.

Source of variation		Body weight (kg)	Feed intake (kg)	Feed conversion ratio	Rump (cm)	Scrotal size (cm)
Genotype	DU	42.24±4.58[b]	10.22±1.41[b]	5.05±1.37[a]	51.16±1.77	20.50±0.12
	HY	44.11±1.83[a]	12.78±0.46[a]	3.70±0.05[b]	52.28±2.10	19.00±0.84
	LW	42.40±1.91[b]	10.24±0.80[b]	4.32±0.21[a]	50.16±1.36	17.67±0.33
Sex	M	42.14±3.55	9.72±1.15[b]	5.15±1.04	52.25±1.51	18.44±0.91
	F	43.69±1.66	12.44±0.58[a]	3.57±0.14	50.15±1.19	
Genotype×Sex	DU×M	46.00±16.00	7.35±2.56	7.99±4.96	54.50±2.50	20.50±0.27
	DU×F	41.20±4.09	12.18±1.36	3.40±0.07	49.20±1.98	
	LW×M	39.00±2.88	8.85±1.22	4.58±0.31	50.00±1.83	17.67±0.4
	LW×F	45.43±2.13	11.63±0.85	3.99±0.25	50.14±2.12	
	HY×M	50.00±0.12	14.65±0.32	3.41±0.14	56.00±0.05	19.00±0.22
	HY×F	42.67±0.67	13.06±0.33	3.27±0.04	50.33±2.19	

Means with different superscripts in the same column are significantly different ($P < 0.05$).

Table 3. Least squares means for performance characteristics at 56 days.

Source of variation		Body weight (kg)	Feed intake (kg)	Feed conversion ratio	Rump depth (m)	Scrotal size (cm)	Back fat thickness (cm) 1st rib	Back fat thickness (cm) 10th rib
Genotype	DU	58.74±6.09	12.36±1.47	4.04±0.11	49.07±1.43	20.50±0.12	2.83±0.12	2.08±0.39
	HY	67.61±4.87	13.06±1.14	4.20±0.25	51.41±1.22	19.00±0.26	3.38±0.39	0.62±0.38
	LW	61.90±3.30	12.05±0.71	4.13±0.10	50.83±1.46	17.67±0.22	6.79±0.33	2.32±0.57
Sex	F	67.03±2.42	13.49±0.62	3.97±0.08[b]	51.61±0.93	-	3.22±2.95	1.54±0.55
	M	58.47±5.42	11.49±1.09	4.27±0.12[a]	49.27±1.83	18.44±0.39	2.46±2.20	1.31±0.32
Genotype×Sex	DU×M	64.00±24.00	13.75±5.09	3.93±0.00	48.00±4.00	20.50±0.19	2.75±0.25	2.25±0.25
	DU×F	59.20±4.32	12.40±1.35	3.99±0.16	50.20±1.53	-	2.90±0.10	1.90±0.90
	LW×M	51.83±2.74	10.04±0.53	4.32±0.15	49.17±2.54	17.67±0.43	2.90±0.10	1.36±0.41
	LW×F	71.14±2.51	13.92±0.72	3.94±0.10	52.43±1.57	-	3.00±0.00	2.00±1.00
	HY×M	79.00±0.40	13.40±0.18	4.63±0.92	53.00±0.11	19.00±0.72	3.00±0.10	0.5±0.19
	HY×F	66.67±5.33	13.62±1.61	3.96±0.27	51.67±1.67	-	-	-

Means with different superscripts in the same column are significantly different (P < 0.05).

size (20.50 cm). Moreover, Large White (LW) had the highest means for back fat thickness at 1st rib and 10th rib with 6.79±0.33 cm and 2.32±0.01 cm accordingly.

The sex effect was not significantly varied (P<0.05) for all the parameters except for feed conversion ratio with highest mean of 4.27±0.12 recorded for male sex while female has the lowest mean value of 3.97±0.08. The genotype-sex interaction was also of no significant variation (P<0.05) for all performance characteristics at 56 days.

Table 4 shows the estimated least-squares means with their corresponding standard errors for the linear body measurements at 35 days of the experiment. The analyses of variance indicated strong significant (P<0.05) effects of genotype on all the linear parameters. It exerted significant (P<0.05) influence on tail length, shoulder-tail and body length with the highest mean from HY: 111.01±3.63 cm, 65.27±1.51 cm and 129.90±11.54 cm, respectively. Sex effect and genotype-sex interaction had no significant influence (P>0.05) on most linear measurements at 35 days of experiment.

Table 5 shows the least squares means for linear measurements at 56 days of the experiment. Sex effect exert no significant influence (P>0.05) on all the linear parameters. Genotype effect was significantly varied (P<0.05) for trunk length and body length with HY having highest mean value of 27.10±1.25 cm and 130.48±10.75 cm, respectively and the lowest mean value for trunk length being observed in DU (22.53±1.14 cm) and that of body length in LW (121.22±8.81 cm). However, the genotype-sex interactions had no significant variation (P>0.05) on the parameters at 56 days of the study.

Analyses of variance for the pig body weights at various stages

The least squares mean of analyses of variance for the pig body weights at 21, 35 and 56 days of the experiment are shown in Table 6. The genotype had significant (P<0.05) influence on the body weight at different ages. The Hybrid showed a higher body weight at 21, 35, 56 days of the experiment with mean values of 40.06±2.24, 42.81±2.49 and 52.00±3.24 kg respectively, while

Table 4. Least squares means for linear measurements (cm) at 35 days.

Source of variation		Body-weight (kg)	Height at wither (cm)	Trunk length (cm)	Tail length (cm)	Shoulder-tail (cm)	Chest-girth (cm)	Body length (cm)
Genotype	DU	42.14±1.78	82.75±1.31	21.36±1.03	104.11±1.34[b]	64.28±1.11[b]	79.23±1.57	126.04±4.28[b]
	HY	42.78±2.49	83.53±1.56	27.48±2.35	111.01±3.63[a]	65.27±1.51[a]	79.72±2.22	129.90±11.54[a]
	LW	38.21±1.67	81.05±2.10	24.96±0.79	106.02±2.57[a]	58.40±3.01[ab]	72.43±3.90	119.63±8.74[ab]
Sex	F	41.12±1.52	83.13±1.50	23.90±1.06	107.02±1.91	61.86±2.30	76.93±2.89	122.89±6.44
	M	40.97±1.65	81.76±1.37	25.30±0.96	107.07±1.81	63.44±1.00	77.33±1.44	127.48±5.49
Genotype×Sex	DU×M	40.17±2.81	80.92±2.03	22.58±0.67	103.50±1.69	64.42±1.42	75.17±2.45	109.25±6.36
	DU×F	41.69±2.31	82.77±1.73	19.92±1.84	102.69±2.11	64.54±1.75	78.69±1.98	118.00±5.75
	LW×M	38.00±1.84	79.80±2.05	23.80±1.05	103.60±2.57	60.60±1.48	74.50±1.74	126.30±8.13
	LW×F	39.64±2.79	83.18±3.58	26.09±1.10	109.27±4.28	56.09±5.64	72.82±7.48	125.91±15.42
	HY×M	46.75±3.25	86.50±4.50	33.50±8.50	120.00±13.00	64.50±0.50	81.00±2.00	142.00±36.00
	HY×F	41.50±3.08	83.00±1.61	25.00±1.37	108.00±2.46	65.00±2.05	79.17±2.96	124.33±12.10

Means with different superscripts in the same column are significantly different (P < 0.05).

Table 5. Least squares means for linear measurements (cm) at 56 days.

Source of variation		Body-weight (kg)	Height at wither (cm)	Trunk length (cm)	Tail length (cm)	Shoulder-tail (cm)	Chest-girth (cm)	Body length (cm)
Genotype	DU	50.20±2.09	85.50±1.17	22.53±1.14[b]	108.02±1.28	65.98±1.00	81.51±1.64	127.84±4.22[a]
	HY	51.91±3.24	84.08±1.51	27.10±1.25[a]	111.17±2.45	66.47±1.31	81.12±2.39	130.48±10.75[a]
	LW	43.33±2.88	82.46±1.34	26.18±0.85[a]	108.64±1.93	60.49±3.09	74.85±4.18	121.22±8.81[b]
Sex	F	48.66±2.36	85.11±1.00	24.82±1.13	109.93±1.51	63.38±2.32	79.17±3.03	124.80±6.49
	M	48.31±1.98	82.91±1.21	25.71±0.72	108.63±1.32	65.25±0.83	79.15±1.57	128.22±5.23
Genotype×Sex	DU×M	46.92±3.27	84.08±1.70	23.66±0.79	107.74±1.38	65.57±1.30	76.25±2.47	110.50±5.92
	DU×F	49.88±2.71	85.85±1.65	21.15±2.06	107.00±2.17	65.77±1.55	80.77±2.08	120.00±5.92
	LW×M	43.55±2.11	80.30±1.84	25.40±1.20	105.70±2.35	63.00±1.12	76.70±2.22	128.20±8.49
	LW×F	44.95±5.25	85.09±1.73	27.00±1.20	112.09±2.78	53.36±5.87	76.18±7.92	127.45±15.41
	HY×M	56.50±5.50	85.50±2.50	28.50±3.50	115.00±6.00	65.50±0.50	83.50±3.50	136.00±29.00
	HY×F	50.50±3.97	84.00±1.88	28.33±1.36	110.33±2.78	66.17±1.78	80.33±3.06	127.50±12.49

Means with different superscripts in the same column are significantly different (P < 0.05).

Table 6. Least squares mean of individual pig weights at 21, 35 and 56 days.

Genotype	21 day weight (kg)	35 day weight (kg)	56 day weight (kg)
Duroc	39.24±1.78[a]	40.96±1.78[a]	48.46±2.09[a]
Large White	36.38±1.61[b]	38.86±1.67[b]	46.24±1.83[b]
Hybrid	40.06±2.24[a]	42.81±2.49[a]	52.00±3.24[a]

Means with different superscripts in the same column are significantly different (P < 0.05).

the Large White (36.38±1.61, 38.86±1.67 and 46.24±1.83 kg) had the lowest mean weight among the three genotypes under study. Duroc performed averagely among the three genotypes with the mean values of 39.24±1.78, 40.96±1.78 and 48.46±2.09 kg for days 21, 35 and 56 accordingly. Hence, the three pig genotypes were statistically different.

DISCUSSION

Performance characteristics at various stages

From this study, it was observed through the analytical results that there were differences in body weight, feed intake, feed conversion ratio, rump and scrotal size of genotypes of the pigs at different days considered in the study. These differences in genotype performance were due to genetic makeup of the individual pigs and environment provided for gene expression. This is in line with Johan (2004) who stated that genotypes differed in their mature composition and how they developed towards it. This study is also in concord with the result of Yoosuks et al. (2012) who studied the effects of genotype and sex on predicted feed intake and performance of growing pigs. Fleming et al. (2018) also stated that genetic differences could be found between breeds, between genetic lines within a breed and between individuals within a line. The cross bred pig (Hybrid) showed the best performance among the three breeds for body weight, feed intake and feed conversion ratio. This showed that the Hybrid has harnessed the best gene from the two parents of different genotypes in order to improve their performance. Fitzhugh et al. (1975) and Fleming et al. (2018) remarked that crossbreeding combined differences in genetic merit for specific characters to synchronize effective performance characteristics and adaptability resources that were most economical.

Moreover, Duroc had the highest means for the feed conversion ratio. This means that they utilized feed better than the Large White and the Hybrid. This is in line with the result of Debreceni et al. (2018). These authors reported highest feed intake and feed conversion ratio in Mangalitsa breed of pig with better average daily gains in Large White and Hybrid (crossbred of Mangalitsa and Duroc). Also, at 56 days of the study, Large White (LW) had the highest means for back fat thickness at 1st rib and 10th rib. This implies that the genotype has the ability to deposit fat compared to others and this could be improved upon during breeding programmes. Furthermore, sex was also a major source of influence on the performance characteristics of the three breeds especially for feed intake and feed conversion ratio. The study showed that the female ate more than the male and had a higher feed conversion ratio than the male. This might be attributed to differences in the physiological processes in the two sexes.

The female ate more feed to regain losses during estrus, production of eggs and fat deposition; hence they were good feed converter. This observation agrees with Chineke (2005) and disagreed with the report of Ozimba and Lukefahr (1991) on the study of rabbit performance and Yoosuk et al. (2012) on the effect of sex on pig performance. The effect of sex for other traits at various ages was similar. The females had heavier body weights than males which disagreed with the findings of Hanne et al. (2018).

Linear body measurements (cm) at various stages

Genotype strongly influenced linear traits at various stages of the experiment. There were consistent increases in linear measurements from day 35 through 56 days. This was expected since breed combinations promote growth, which is in turn associated with increase in mature body size. In general, each measurement studied increased with increase in age in each genotype. Ozoje and Herbert (1997) reported similar findings in crossbreeding experiments involving goats and observed further that these increases, calculated as a percentage of their values at birth, were at different rates. The significant effect of genotype on the growth of the pigs is in line with the result of Rauw et al. (2017) who reported significant effect of genotype in pig growth performance, when they studied the effects of diet and genetics in growth performance of pigs. Among the genotypes, Hybrid was generally superior in linear traits over other genotypes. Differences in linear traits reflect useful measures that depict the size and shape of animal (Chineke, 2005). The Hybrid showed the best performance for body length, shoulder to tail and tail length among the three breeds. This could be attributed to the contribution of genes from the two parents that enhanced a better performance of the cross bred and made it more superior to the parents.

Sex exerted no significant influence on all the body measurements considered at various stages of the study; though, the male was observed to have the highest mean values for all the linear measurements except for the height at wither where the dam had the highest mean. Similar results have been reported by Chineke et al. (2002a). The male had bigger and longer body in most measurements taken than the females and was contrary to the findings of Akpan (2000) and Chineke et al. (2002b). The significant effect of sex on linear body measurement of growing pigs from this study was in concord with the result of Onyimonyi et al*.* (2010) and Egena et al*.* (2010). These authors reported that body linear measurements were influenced in growing pigs that are males.

Body weights at various stages

The genotypes showed significant differences among the individual pig weights at different stages of the study. The Hybrid showed a higher body weight at 21, 35 and 56 days of the experiment. Similar observation was recorded for Thapa and Timsina (2018) for production performances of crossbred pigs. These authors attributed the higher performance to heterosis. Thus, cross breeding would lead to improvement in production traits. Moreover, Duroc showed a better performance in body weight as compared with the Large White at all stages of the study. This could mean that the Duroc had more body conformation and feed utilization than the Large White.

Conclusion

The performance traits, linear body measurements were influenced differently by factors considered in the study. The genotype and sex were the main source of variation in almost all the traits studied. The body weights and the other measurements considered in this study increased with increase in age, implying a better performance in the long run and heavier market weights and sizes. Furthermore, improvement in the production characteristics of the pigs is feasible through genotype manipulation. The crossbred pig had the best performance in terms of the measurements considered in this study.

RECOMMENDATIONS

From this study, it could be recommended that crossbreeding programs for pigs will improve the existing genotypes and this should be embarked upon. Also, provision of suitable environment such as housing and nutrition will enhance pig production in Nigeria.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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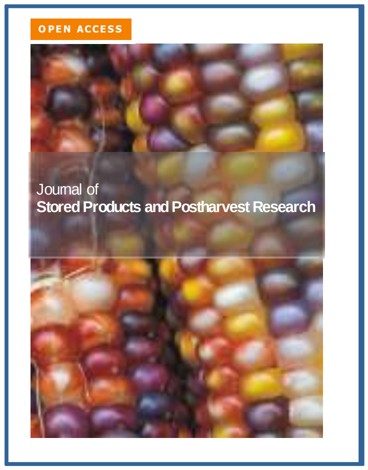

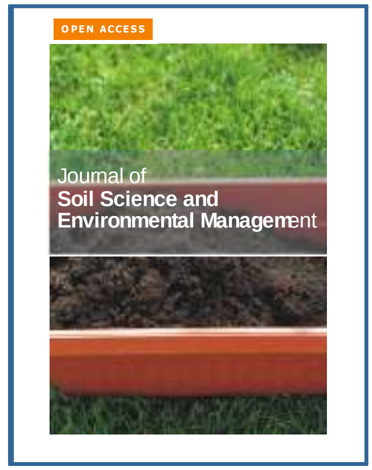

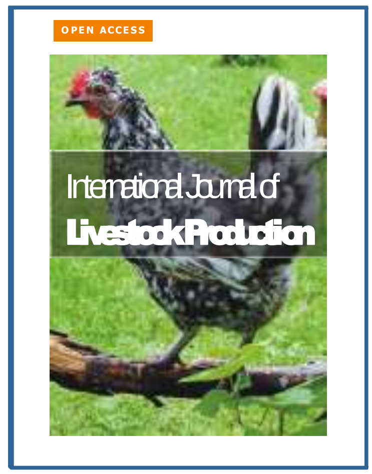

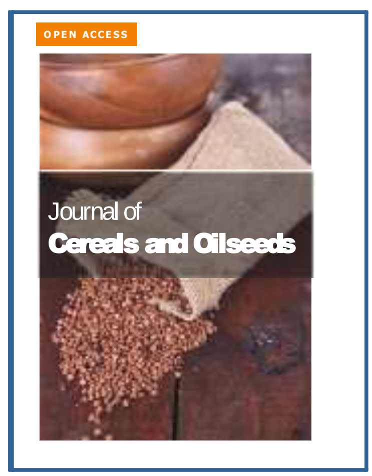

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