Reproductive efficiency in naturally serviced and artificially inseminated beef cows

Article *in* Tropical Animal Health and Production · September 2019

DOI: 10.1007/s11250-019-01889-z

CITATION
1

READS
218

7 authors, including:

Soul Washaya
Great Zimbabwe University
18 PUBLICATIONS **87** CITATIONS
SEE PROFILE

Bruce Tavirimirwa
Matopos Research Institute
13 PUBLICATIONS **63** CITATIONS
SEE PROFILE

Givious Sisito
Matopos Research Institute
23 PUBLICATIONS **60** CITATIONS
SEE PROFILE

Grace Tambo
Matopos Research Institute
2 PUBLICATIONS **2** CITATIONS
SEE PROFILE

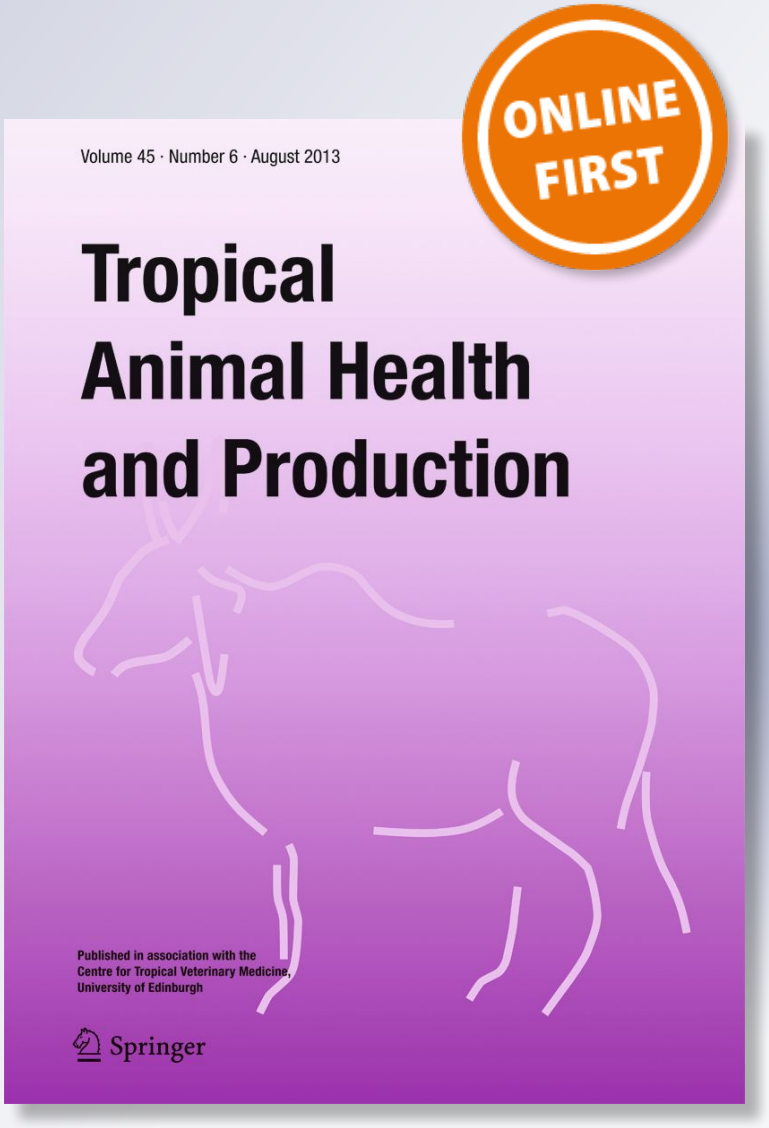
Reproductive efficiency in naturally serviced and artificially inseminated beef cows

S. Washaya, B. Tavirimirwa, S. Dube, G. Sisito, G. Tambo, S. Ncube & X. Zhakata

Tropical Animal Health and Production

ISSN 0049-4747

Trop Anim Health Prod
DOI 10.1007/s11250-019-01889-z



Springer

Tropical Animal Health and Production
https://doi.org/10.1007/s11250-019-01889-z

REGULAR ARTICLES

Reproductive efficiency in naturally serviced and artificially inseminated beef cows

S. Washaya[1,2] · B. Tavirimirwa[3] · S. Dube[4] · G. Sisito[3] · G. Tambo[3] · S. Ncube[3] · X. Zhakata[3]

Received: 3 September 2018 / Accepted: 11 April 2019

Abstract

A study was conducted to compare conception rates in 71 Tuli and 86 Afrikander beef cattle bred using either artificial insemination (AI) or the bull. Animals were bred using either artificial insemination or natural service at Matopos Research Station. Animals were grouped into three groups of heifers (parity 0; P0), second calvers (parity 1; P1) and mature cows (parity 2; P2) before being randomly assigned to one of the two breeding methods. A binary logistic regression was used for statistical analysis where breeding method (AI vs natural service) was the treatment factor and conception rate was the measured response while breed, parity and last calving date were non-treatment factors. No significant differences were observed in conception rates between breeds ($P > 0.05$). However, the method of breeding animals, parity and calving interval affected ($P < 0.05$) conception rates. The breeding method, parity and calving interval had a positive Kendall's tau-b correlation coefficients to conception. More animals were pregnant when AI (77.6%) was used compared with natural mating (56.79%). Conception rates were significantly lower ($P < 0.05$) in C1 compared with C2 cattle. The odds ratio for breeding method and parity are positive and significant ($P < 0.05$). In conclusion, the study confirms that artificial inseminated animals had similar conception rates to naturally serviced animals for both Tuli and Afrikander breeds. As such, artificial insemination technology can be used to complement or substitute natural service in indigenous cattle's of Zimbabwe.

Keywords Indigenous cattle · Breeding method · Pregnancy rates · Smallholder

Introduction

A high conception rate, which in the context of cattle production is defined as the number of pregnancy observed per population of females bred/mated in a defined breeding season, is critical in terms of profit potential in any beef operation (Perry 2005). There are indications of major revenue losses in Zimbabwe smallholder beef industry due to low conception rates (Mavedzenge et al. 2006). Two types of breeding systems are used in Zimbabwe, namely natural service and artificial insemination (AI). Artificial insemination is however not common in communal cattle production systems. Natural service is the traditional bull breeding method in which bulls service the cows through random or controlled mating. Random mating is widely practiced in Zimbabwe communal cattle production systems (Assan 2012) which hold over 90% of cattle population in the country (Mavedzenge et al. 2006; Ndebele et al. 2007). Natural service is the easiest method of breeding cattle for producers that may not have the finance (Valergakis et al. 2007), time and labour required to implement oestrus synchronisation and detect heat (Mugisha et al. 2014). However, natural service has a number of challenges that include lower genetic progress per generation, high risk of inbreeding related problems, transmission of infections during service and a premium bull may only serve a limited number of animals per year (Patel et al. 2017).

Reproductive performance varies with breeds and different cattlemen tend to choose the breeding system which

✉ S. Washaya
jabulaniwashaya@yahoo.com

[1] Department of Agriculture, College of Health, Agriculture and Natural Sciences, Africa University, P Bag 1320, Mutare, Zimbabwe

[2] Faculty of Science and Agriculture. Department of Livestock and Pasture Science, University of Fort Hare, King Williams Town Road, P. Bag X1314, Alice 5700, South Africa

[3] Department of Research and Specialist Services, Matopos Research Institute, P Bag k5137, Bulawayo, Zimbabwe

[4] Faculty of Agriculture and Natural Resources Management, Midlands State University, Gweru, Zimbabwe

Published online: 07 May 2019

gives appropriate consideration to the best, least cost and labour effective way of getting cows back in-calf in the shortest period. Although artificial insemination programs have been effectively implemented, mostly on exotic breeds, at commercial level in the country, the technology has been poorly received by small-scale farmers (Tada et al. 2010). Furthermore, government officials and livestock producers in Zimbabwe are uncertain of the effectiveness of AI on pregnancy rates in indigenous cattle. There is lack of awareness coupled with inconclusive data on AI in Zimbabwean communal areas. Reports by Kaziboni et al. (2004), Ndebele et al. (2007) and Tada et al. (2010) show that the communal production systems repeatedly produce very poor reproductive performance results where AI has been used in indigenous breeds. Researchers and extension experts in Zimbabwe therefore need to conduct detailed studies and awareness campaigns to generate information and make farmers more aware of the potential benefits of AI in the small-scale sector through generation and capturing of adequate data to proffer solutions to question being raised by farmers. Therefore, it is essential for cattle breeders to evaluate the reproductive performance of naturally serviced and artificially inseminated cattle breeds' common in the small holder sector. The current study aims to compare the conception rates of naturally serviced and artificially inseminated Tuli and Africander cows.

Materials and method

Study site

The investigation was carried out at Matopos Research Institute, Lucydale section. Matopos Research Station (20° 23′S, 31° 30′E) is situated 30 km south west of Bulawayo in Zimbabwe at an altitude of 800 m and experiences low erratic rainfall (< 450 mm) per annum (Homann et al. 2007). It is in agro-ecological zone IV. The region is characterised by high summer temperatures, maximum and minimum mean temperatures of hottest months are 21.6 °C and 11.4 °C respectively, and frequent droughts (Hagreveas et al. 2004).

Study animals and selection criteria

A total of 157 animals were used in the study; 71 Tuli and 86 Africander breeding animals were selected from the Matopos stud herds. Grouping of animal and allocation of treatments is shown in Table 1. A pregnancy diagnosis by rectal palpation was done on all animals prior to breeding. Empty cows and heifers with a body condition score of 3 and 4 (scale 1–5) were selected for the trial.

Table 1 Treatment factors, breeding method and the measured response of breeding indigenous cattle at Matopos Research Station

Breed										
Breeding method	Tuli					Afrikander				
	Parity			LCD		Parity			LCD	
	P0	P1	P2	C1	C2	P0	P1	P2	C1	C2
AI	12	18	8	13	9	12	19	8	14	10
Natural	12	18	8	18	12	14	19	8	19	12
Total	24	38	16	31	21	26	38	16	33	22

P0 = heifers P1 = animals with 1 calving; P2 = mature cows; C1 = calving interval < 365 days, C2 = calving interval > 365 days

Natural service groups and insemination management

All artificially inseminated animals were herded and penned for the duration of the experiment lasting 48 days. To reduce inseminator variation, one inseminator was used on all inseminated cattle. All animals in the insemination program were synchronised at the onset of the program using a prostaglandin analogue. Animals which exhibited standing heat were inseminated once with the reminder inseminated as they came on heat naturally over a period of 48 days (between January and February 2016). Naturally serviced animals were put in bulling herds at a ratio of 20 cows per bull for 3 months (January to March 2016). Bulls were examined prior to bulling by an experienced veterinarian and each bull used was awarded with a fitness certificate.

Insemination protocol used

On day zero, animals were injected with 2-ml estrumate, on day 12, another 2 ml of estrumate was given after which heat signs were observed. All animals that responded to the drug were inseminated over a period of 6 days. Then, non-responsive animals were observed and inseminated once they show oestrus signs over a total period of 48 days, thus all animals were only inseminated once and no repeat breeding was considered.

Data collection

Animal ID number (ear tag), age, live body weight, last calving date (from onset of the trial), parity and the breed of animals, breeding method (inseminated vs natural mating) were recorded. Pregnancy diagnosis by rectal palpation was conducted 3 months post-insemination and bulling to determine the number of animals that conceived.

Statistical analysis

A binomial logistic regression was used to rank factors affecting conception rate in Tuli and Afrikander breeds in SPSS version 16.0 (2009) using the following model:

$$\text{Ln}\,[p/1-p] = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 X_3 \ldots \beta_k X_k + \varepsilon$$

p	probability of conception
βo	intercept
β_1–β_4	regression coefficients of ranked factors on Ln [p/1−p] (pregnant; empty) [p/1−p] odds ratio referred to the odds of conception computed for each estimator (β_1–β_4)
ε	random residual error
β_1	effect of breed (X_1; 1,2)
β_2	effect of parity (X_2; 1,2,3)
β_3	effect of treatment, i.e. breeding method (X_3; 1.2)
β_4	effect of days calving interval (X_4;0, < 365, > 365)

A Kendall's tau-b correlation was computed to assess the relationship among predictors and the response variable.

Results

Out of a total of 157 animals bred; more than 50% were Afriakander, while more than 50% were artificially inseminated and an average of 70% got pregnant as shown in Table 2.

Table 2 Overall performance of Tuli and Afrikander breeding cows bred by either AI or NS at Matopos Research Station

			N	Percent (%)
Dependent variable	Pregnant status	Empty	52	33.1
		Pregnant	105	66.9
		Total	157	100.0
Treatment factor	Breeding method	AI	81	51.6
		NS	76	48.4
		Total	157	100.0
Non-treatment factors	Cattle breed	Afrikander	86	54.8
		Tuli	71	45.2
		Total	157	100.0
	Parity Level	0	64	40.8
		1	61	38.9
		2	32	20.4
		Total	157	100.0
	Calving interval	0	50	31.8
		< 365	64	40.8
		> 365	43	27.4
		Total	157	100.0

AI artificial insemination, *NS* natural service

The pregnant status for Afrikander and Tuli are shown in Table 3. The breeding method, parity and calving interval significantly influenced conception in cows with positive Kendall's tau-b correlation coefficients ($P = 0.009$, 0.008 and 0.037), respectively. Artificially inseminated animals showed a higher ($P < 0.05$) pregnancy rate compared with naturally serviced animals, while pregnancy rate increased with parity from heifers to mature cows.

Animals that have a calving interval less than 365 days had a higher ($P < 0.05$) conception compared with those with a longer calving rate. The relationship between calving to re-conception was also determined and results are shown in Fig. 1. Last calving date significantly influenced ($P < 0.05$) conception rates. Conception rates were low in C1 than C2 animals. Conception rate was observed to be 17.3% correlated to calving dates.

Data was subjected to GLM (binary logistic regression) to determine the relationship between pregnancy vs breed, parity, calving interval and breeding method, and the results are shown in Table 4.

The breeding method and parity had a significant effect ($P < 0.05$) on the pregnancy status of cows. An increase of just one cow will be associated with a 2.5 and 1, 75 increase in pregnancy rate for breeding method and parity, respectively. The Wald statistics for breed and calving interval indicate that the constant is not significantly different from zero; however, the odds ratio shows that any increase in the number of cows would result in a 0.5 and 1.5 increase in the pregnancy rate of cows, respectively.

Discussion

High conception rates observed in artificially inseminated animals compared with natural mating effectively disapprove conclusions by Lemaster et al. (2001) and Toleng et al. (2001) who concluded that AI programs in tropical cattle have conception rates, which seldom exceed 30%. As such, artificial insemination technique can be adopted and effectively used in breeding under communal to semi-intensive production systems. Furthermore, there is an added advantage of rapid genetic progress derived from the use of semen from performance tested bulls (Nimbkar et al. 2008). The high conception rate of indigenous cows observed in this study compared with the natural service is also in contrast with the observation of Tada et al. (2010) and Mukasa-Mugerwa et al. (1991) who have reported low conception rates in artificial insemination programs involving indigenous cattle in communal areas of Zimbabwe. Kaziboni et al. (2004) however reported relatively comparable conception rates of 59% in an artificial insemination study done in the smallholder dairy scheme of Nharira-Lancashire in Zimbabwe. The possible reasons for the high pregnancy rate

Table 3 Pregnancy status of Afrikander and Tuli cattle at Matopos Research Station

	Breeding method		Breed		Parity			Calving interval		
	AI	NS	Afrikander	Tuli	P0	P1	P2	P0	C1	C2
Empty *N*	18	33	33	18	23	21	7	23	16	12
Empty %	22.8	41.8	34.8	25.0	46.9	27.6	21.2	46.9	24.6	27.6
Pregnant *N*	61	46	53	54	26	55	26	26	49	31
Pregnant%	77.2	58.2	61.6	75	53.1	72.4	78.8	53.1	75.4	72.1
Kendall's tau-b	0.009	0.009	0.068	0.068	0.008	0.008	0.008	0.037	0.037	0.037

observed in the current study is because the study was undertaken at a research institute where among other factors required for successful pregnancy, highly trained AI technicians working on the station, took due attention on oestrus observations as it has been noted that lower conceptions in artificially inseminated indigenous cows are related to the difficulty of detecting oestrus signs in tropical cattle breeds (Woldu et al. 2011). Cows that originated in the sub-tropical regions tend to exhibit subdued oestrus signs, often for a shorter period compared with exotic breeds (Kaziboni et al. 2004) making estrus detection more difficult than in *Bos taurus* cattle. The present study showed that a high level of education of AI technicians has a direct bearing on pregnancy rates as was reported in other studies (Fu and Zhou 2002). Xu et al. (1998) observed marked conception rate increase of between 60 and 70% in artificially inseminated cows following refresher training of inseminators and on farm instructions to farmers in small-scale farming communities of China. Therefore, research from the current study affirms this observation. Tada et al. (2010) highlighted that inseminator efficiency and proper heat detection account for almost 20% of the variability of conception rates in AI program. Accordingly, technical training on AI and reproductive physiology to improve heat detection efficiency, AI timing, record keeping and semen handling procedures are therefore important to attain high conception rates in AI programs being carried out in communal areas of Zimbabwe.

Non-significant effect of breeds on the conception rates was also expected in line with reports by Moyo et al. (1996). However, a greater proportion of Tuli animal's conceived compared with Afrikander cattle in the current study. This is in line again with findings by Moyo et al. (1996) who highlighted that Tuli cattle are relatively more fertile compared with Afrikander cattle with average calving rates of 69% and 57%, respectively. Although breed was not significant in influencing conception rate, the odds ratio is still positive, which might mean that if one of the variables changes, conception rate might change in favour of one of the breeds in this case Tuli cows. The breeding method, parity and calving interval showed a positive odds ratio, this was expected and confirm earlier findings by Woldu et al. (2011)

In the present study, it was observed that conception rate was lower in heifers and second calvers compared with older

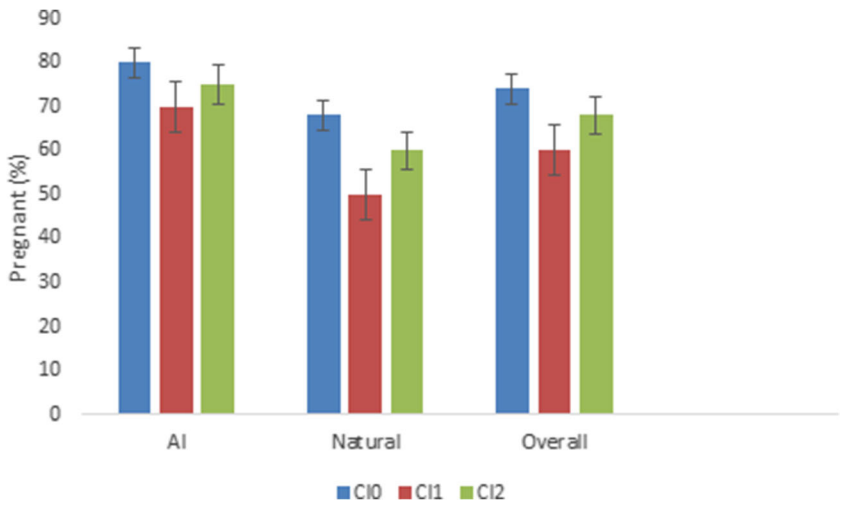


Fig. 1 Effects of calving interval on conception rate of artificially inseminated and naturally serviced Tuli and Afrikander cattle

Table 4 Logistic regression for Afrikander and Tuli breeds bred using either AI or NS at Matopos Research Station

	B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I. EXP(B)	
							Lower	Upper
Constant	0.702	0.307	5.224	1	0.022	2.018		
Breed	−0.677	0.360	3.540	1	0.060	0.508	0.251	1.029
Breeding method	0.927	0.357	6.720	1	0.010	2.526	1.254	5.089
Parity	0.627	0.5329	4.545	2	0.001	1.748	−0.417	1.672
Calving interval	0.35	0.00079	3.802	2	0.28	1.462	−1.581	−0.90

animals. The findings are in line with those of Kaziboni et al. (2004). Reproductive fertility increases with parity which then declines with increasing age. The differences in conception rates are probably because the majority of heifers and young cows in first lactation would still be undergoing skeletal and soft tissue growth hence increased competition of nutrients for growth and development of the animal itself over reproduction as tropical cattle breeds mature late compared with exotic breeds. Short and Adams (1988) ranked the metabolic use of available energy in ruminants, prioritising each physiological state in order of importance as follows: (1) basal metabolism; (2) activity; (3) growth; (4) energy reserves; (5) pregnancy; (6) lactation; (7) additional energy reserves; (8) estrus cycles and initiation of pregnancy; and (9) excess energy reserves.

Records for last calving dates were used as a determent of calving interval (CI). Calving interval is an essential parameter in gauging the reproductive efficiency of cattle production enterprises and is a function of previous calving date (MacGregor and Case 2000). The low conception rates exhibited by animals with a longer CI were also expected. This phenomenon might be due to inherent reproductive problems including but not limited to abnormally long postpartum anoestrous, uterine pathology and reproductive diseases. Furthermore, this may also help explain the low conception rates reported in AI programs from communal areas where farmers tend to put forward problematic animals and repeat breeders for AI due to misconceptions that AI is a remedy to cows with fertility problems (Chatikobo 2017). Low conception rates for animals having CI greater than 24 months were also reported by Chimonyo et al. (2000) and Homann et al. (2007) in smallholder farming cattle production systems in Zimbabwe. This indicates reproductive inefficiency. Infections of the reproductive tract, many of which are spread by the indiscriminate mating in communally grazed cattle (Tada et al. 2010), increase the period from calving date to conception as these conditions negatively affect the conception ability of the affected animals. Xu and Burton (2003) reported that non-genetic factors which include optimum herd management, absence of brucellosis and stringent culling of infertile cows can improve the mean CI. This suggests that if AI is performed in well-managed herds with good nutritional and health status, high conception rates will be attained as short calving interval has been associated with such herds.

Conclusion and recommendations

The study confirms that conception rates favourable or similar to when cattle are exposed to natural service can be obtained through artificial insemination in Tuli and Africander breeds. The high AI conception rate attained in this study is encouraging. Besides demystifying the misconception that AI is unsuitable for local breeds, the results provide critical insights on the fact that if appropriate insemination procedure is employed, AI is highly effective as an alternative breeding tool in indigenous breeds of Zimbabwe. Formation of a regulatory authority for inseminators is recommended. This can be in the form of a government-backed association of inseminators which can be tasked to regularly provide refresher training courses to inseminators and conscientise smallholder farmers on AI technical aspects as well as serve as information hubs for farmers. This will help curb proliferation of unregulated AI technicians who may be contributing to poor conceptions and negative AI publicity reported in communal areas through poor inseminator efficiency and using semen from unknown sources.

Acknowledgements The authors appreciate input by Matopos Research Institute Lucedale Section Staff, in particular Mr. Kameron Moyo for his resilience during the execution of the study.

Funding information The study was financially supported by Stichting Nederlandse Vrijwilligers (SNV) Zimbabwe (Grant number 104-86-3-1) under the auspices of a matching grant awarded to Matopos Research Institute.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Assan, N., 2012. Genetic improvement and utilization of indigenous cattle breeds for beef production in Zimbabwe: past, present and future prospects, Scientific Journal of Agriculture, 1, 1–13

Chatikobo, P., 2017. Proceedings from a Cattle artificial insemination and management course held at Matopos Research Institute, Bulawayo 13–17 February 2017.

Chimonyo, M., Kusina, N.T., Hamudikuwanda, H., Nyoni, O., Ncube, I., 2000. Effects of dietary supplementation and work stress on ovarian activity in non-lactating Mashona cows in a smallholder farming area of Zimbabwe, Animal Science 70, 317–323

Fu, C., Zhou, Y., 2002. Measures for raising conception rate in dairy cattle. Journal of China Dairy Cattle, 1, 37–39

Hagreveas, S.K., Bruce, D., Beffa, L.M., 2004. Disaster mitigation options for livestock production in communal farming systems in Zimbabwe. Background information and literature review. ICRISAT and FAO Rome, Italy 56pp.

Homann, S., van Rooyen, A., Moyo, T., Nengomasha, Z., 2007. Goat production and marketing: Baseline information for semi-arid Zimbabwe, International Crops Research Institute for the Semi-Arid Tropics: Bulawayo.

Kaziboni, S., Kusina, N.T., Sibanda, S., Makuza, S., Nyoni, O., Bhebhe, E., 2004. Performance of artificial insemination in smallholder dairies of Nharira-Lancashire in Zimbabwe. Livestock Research for Rural Development. Vol. 16, Art. #25.Retrieved August 8, 2018, from http://www.lrrd.org/lrrd16/4/kazi16025.htm

Lemaster, J.W., Yelich, J.V., Kempfer, J.R., Fullenwider, J.K., Barnett, C.L., Fanning, M.D., Selph, J.F., 2001. Effectiveness of GnRH plus prostaglandin F2α for estrus synchronization in cattle of *Bos indicus* breeding, Journal of Animal Science, 79, 309–316.

MacGregor, R.G., Case, N.H., 2000. The effects of maternal calving date and calving interval on growth performance of beef calves, South African Journal of Animal Science, 30, 70–76

Mavedzenge, B.Z., Mahenehene, J., Murimbarimba, F., Scoones, I., Wolmer, W., 2006. Changes in the livestock sector in Zimbabwe following land reform: the case of Masvingo province. Livestock Research and Rural Development www.lalr.org.za Accessed 17 May 2011

Moyo, S., Swanepoel, F.J.C., Rege, J.E.O., 1996. Evaluation of indigenous, exotic and crossbred cattle for beef production in a semi-arid environment: reproductive performance and cow productivity, Proceeding of Australian Society of Animal Production, 21, 204–206

Mugisha, A., Kayiizi, V., Owiny, D., Mburu, J., 2014. Breeding services and the factors influencing their use on smallholder dairy farms in central Uganda. Veterinary medicine international vol. 2014, Article ID 169380, 6 pages.

Mukasa-Mugerwa, E., Tegegne, A., Mesfin, T., Telku, Y., 1991. Reproductive efficiency of *Bos indicus* cows under artificial insemination management in Ethiopia, Animal Reproduction Science Journal, 24, 63–72.

Ndebele, J.J., Muchenje, V., Mapiye, C., Chimonyo, M., Musemwa, L., Ndlovu, T., 2007. Cattle breeding management practices in the Gwayi smallholder farming area of South-Western Zimbabwe. Livestock Research for Rural Development. Volume 19, Article #183. Retrieved August 8, 2018, from http://www.lrrd.org/lrrd19/12/ndeb19183.htm

Nimbkar, C., Gibson, J. ,Okeyo, M., Boettene, P., Soelknor J., 2008. Sustainable use and genetic Improvement. Animal Genetic Resources Information AGRI, 42, 49–69.

Patel, G k., Haque, N., Madhavatar, M., Chaudhari, AK., Patel, D k., Bhalakiya, N., Jamnesha, N., Patel, P., Kumar, R., 2017. Artificial insemination: A tool to improve livestock productivity. Journal of Pharmacognosy and Phytochemistry 1: 307–313

Perry, G., 2005. Factors affecting breeding success. Range Beef Cow Symposium. Paper 37. http://digitalcommons.unl.edu/rangebeefcowsymp/37 (accessed 10 October 2018)

Short, R.E., Adams, D.C., 1988. Nutritional and hormonal interrelationships in beef cattle reproduction, Canadian Journal of Animal Science, 68, 29–39.

Tada, O., Masamha, B., Gadzirayi, C.T., 2010. Efficacy of crestar (progesterone analogue) and prosolvin (prostaglandin analogue) in heat synchronization of indigenous smallholder dairy and commercial beef cows. Electronic Journal of Environmental, Agricultural and Food Chemistry. 9(2), 385–394

Toleng, L., Yusuf, SH., Hamid, M., 2001. The use of progesterone RIA to increase efficiency and quality of artificial insemination services of beef cattle in South Sulawesi, Indonesia. Radioimmunoassay and Related Techniques to improve artificial insemination programmes for cattle for cattle under tropical and subtropical conditions IAEA-TECDOC-1220, IAEA, Vienna pp37–43

Valergakis, G.E., Arsenos, G., Banos, G., 2007. Comparison of artificial insemination and natural service cost effectiveness in dairy cattle. Animal, 1(2) 293–300.

Woldu, T., Giorgis, Y.T., Haile, A., 2011. Factors affecting conception rate in artificially inseminated cattle under farmers' condition in Ethiopia, Journal of Cell and Animal Biology, 5(16), 334–338

Xu, Z, Burton, L., 2003. Reproduction performance of dairy cows in New Zealand. Livestock improvement co-operation. Proceedings of a Seminar of the Society of Dairy Cattle Veterinarians of New Zealand Veterinary Association, 17, pp. 23–41.

Xu, Z.Z., McKnight, D.J., Vishwanath, R., Pitt, C.J., Burton, L.J., 1998. Estrus detection using radiotelemetry or visual observation and tail painting for dairy cows on pasture. Journal of Dairy Science, 81, 2890–2896.