Original Research Article

Effect of seasonal mating on birth weights of Mpwapwa breed cattle and its crosses produced at Tanzania Livestock Research Institute – Mpwapwa, Tanzania

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ABSTRACT

Aims: A retrospective study was conducted to assess how seasonal mating could influence calf birth weight in cattle among Mpwapwa breed and its four crossbreeds reared at Tanzania Livestock Research Institute (TALIRI) farm.

Study design: This study used farm data collected at TALIRI, Mpwapwa centre. A total of 585 calves of Mpwapwa cattle breed and its four different crosses, born between 2018 and 2023 were included in the study. Among those, 395 were born during the dry season (June to November) while 190 were born during the rainy season (December to May).

Methodology: To assess for significance of differences in mean birth weights between seasons and crossbreeds, a two – way ANOVA with interaction was performed, followed by univariate pairwise comparisons with Bonferroni correction while pairwise differences between crossbreeds were assessed using an independent samples t – test.

Results: The results showed that, mean birth weights differed between seasons ($F=4.88$, $P=.03$) and between calf crossbreeds ($F=17.33$, $P<.001$). The mean birth weight of calves born during the rainy season (24.4kg) was higher compared to that of calves born during the dry season (23.4kg) ($P=.04$). Overall, Vianze calves had highest mean birth weight (26.6kg), followed by Kikombo calves (25.7kg, n = 61), Matondwe (24.5kg, n = 35) and Chibamba calves (24.4 kg, n = 81). Mpwapwa calves had the lowest mean birth weight (22.6kg, n = 344).

Conclusion: These findings demonstrate the importance of strategic feeding especially of pregnant cattle in optimizing subsequent mean calf birth weights. Feeding the pregnant cattle with maize leftovers and hay resulted to higher birth weights. Also the role of cattle crossbreeding programs in improving calf birth weights has been demonstrated.

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Keywords: birth weight, Mpwapwa, crossbreed, season

1. INTRODUCTION

Mpwapwa breed cattle is a composite dual – purpose breed which was established in the 1960s by Tanzania Livestock Research Institute (TALIRI) (then Livestock Production Research Institute) in Mpwapwa district, central Tanzania. The breed was made from 32% Red Sindhi, 30% Sahiwal, 19% Tanzania Shorthorn Zebu, Boran 11% and Ayrshire 8% [1,2]. Mpwapwa breed is renowned for its adaptability to the challenging environmental conditions of the region and its contribution to the livelihoods of local communities. They are well-suited to thrive in the arid and semi-arid conditions characterized by limited grazing resources and fluctuating weather patterns, hence making them a valuable asset for farmers and herders [3–5]. Over time, Mpwapwa cattle have become an integral part of the local culture and economy, serving as a source of meat, milk, and income; contributing considerably to livelihoods of local communities [6–8]. Apart from the economic values of Mpwapwa cattle, they have also been serving as a source of prestige and traditional practices [9,10].

In recent years, efforts have been made to preserve and improve the Mpwapwa breed through selective breeding/crossbreeding programs and conservation initiatives. Among the factors that can be used in the selection process is calf birth weight. Calf birth weight is a critical factor in the health, growth, and overall productivity of cattle. It holds immense importance in the management of livestock for several key reasons. These include health and survival of a calf, growth potential of the calf and milk production of the dam, to mention a few. Ferrell [11] revealed that a lower calf birth weight than optimum increases calf deaths at or near birth and also affects growth rate after birth, energy body reserves, thermoregulatory capability and mature body size of the animal. In addition, according to Holland and Odde [12], calves with low birth weight lack vigor tolerance against pathogens and post-calving life stress from surrounding environment. Calf birth weight data can be used to make informed decisions about which animals to retain for breeding, which can have a long-lasting impact on the quality and productivity of a cattle herd. Thus, economic returns from a cattle operation are closely tied to calf birth weights because cows born with optimum birth weight produce more milk compared to cows born with low birth weight [13]. Therefore, managing and monitoring calf birth weight is a fundamental aspect of cattle breeding and management practices. Among the factors which could influence birth weight of a calf is the season into which a calf is born with several factors coming into play. The season of birth not only influences birth weight but can also have long-term effects on calf growth and development.

For many years, TALIRI Mpwapwa centre has been implementing a seasonal cattle mating program, with two mating seasons per year i.e. March – May and September – November. Apparently, the two mating seasons coincide with the rainy season (December – May) and the dry season (June – November) respectively. The mating seasons lead to two calving seasons i.e. December – February and June – August respectively. Seasonal cattle breeding program is important for the research centre as among others, as it provides reasonable sample sizes of different classes and physiological statuses of cattle for research purposes such as pregnant cows, lactating cows, heifers, yearlings and pre and post-weaning calves.

Therefore, the aim of this study was to assess the effect of the season into which a cow/heifer is mated on the eventual calf birth weight among Mpwapwa breed cattle and their crosses, reared at TALIRI Mpwapwa farm. The results of this study can inform better management practices in the centre and elsewhere with similar settings.

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2. MATERIALS AND METHODS

2.1 Study area

Tanzania Livestock Research Institute (TALIRI) is a public research institute with eight (8) research centres in the country which are located in seven different agro-ecological zones across the country. TALIRI Mpwapwa is one of the two centres situated in the semi–arid central zone. TALIRI Mpwapwa is found in Mpwapwa district in Dodoma region in Tanzania. The research centre receives an average annual rainfall of 660 mm per year, and is situated at an altitude of 1,066 metres above sea level and lies between latitudes 6^{o} 20' South and longitudes 36^{o} 30' East. The rainy season usually lasts for a period of six (6) months which extends from December to May followed by six (6) months of dry season which spans from June to November.

2.2 Study animals

TALIRI Mpwapwa produced a total of 585 calves for five (5) years (from 2018 through to 2023) through controlled breeding method of natural mating. The calves were produced seasonally twice in a year in a period of dry season (between June and August) and in a rainy season (between December and February). This was a result of the seasonal mating twice in a year period i.e. between March and May and also between September and November. Cattle mated between March and May calved in a period between December and February and those mated between September and November calved in a period between June and August. About 67.5% (n=395) of the total calves were born in the dry season and the rest 32.5% (n=190) were born in the rainy season.

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2.3 Description of the calves

The majority of the 585 of the produced calves, were Mpwapwa breed (n = 344). Others were crosses of Mpwapwa with Danish red (also known as "Red Danish" or "Red Dane"), the major dairy cattle of Northern Europe, originating from Denmark. For the purpose of easy identification and reference, these crossbreeds were named as These were named as Chibamba (n = 81) (with a blood composition of 50% Mpwapwa 50% Danish red); Vianze cattle (n = 64) (75% Danish red and 25% Mpwapwa cattle) and Matondwe (n = 35) (75% Mpwapwa cattle and 25% Danish red). The last crossbreed was Kikombo cattle (n = 61) which was made up of 50% Sahiwal, 25% Mpwapwa and 25% Boran.

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2.4 Feeding of the pregnant cattle before calving

Before calving, groups of pregnant cattle were daily grazed randomly in TALIRI Mpwapwa main farm for about 6 – 7 hours on the natural pastures species namely; *Urochloa spp.*, *Panicum maximum, Hyperrhenia rufa, Bothrochloa spp., Digitaria mombasana, Cynodon dactylon, and Cenchrus ciliaris*. They were entirely grazed on the mentioned pastures species during dry and rainy seasons throughout the year. However, in the dry season animals were grazed and fed with crop residuals, which are more readily available during the dry season (after maize corn harvest). At the peak of the dry spell, groups were supplemented with baled hay composed of a mixture of *Cenchrus ciliaris*, *Heteropogon* and *Cyanodon* species.

2.5 Data collection

Several hours after calves were born, licked, suckled and ear tagged, live body weights (kg) were measured using a 300kg capacity mechanical platform scale. During measurement, a

newborn calf was placed on the platform of the analog weighing scale and the observed reading value was recorded.

2.6 Data analysis

Data were entered into Microsoft Excel 2016 spreadsheets, for processing and cleaning. Data analysis was carried out using STATA 14® (Stata Corp. College, Texas, USA). Descriptive statistics were used to establish frequencies and proportions means (with standard deviations), maximum and minimum values. Two–way analysis of variance (ANOVA) was used to determine the effects on the mean calves' birth weights of the mating season and of the calf breed composition. Following a significant two–way ANOVA, univariate pairwise comparisons were performed using one–way ANOVA with Bonferroni correction, to assess for differences in mean birth weights between breeds. Moreover, a comparison of mean birth weights between calves born during the rainy and dry seasons was performed using an independent samples t – test.

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3. RESULTS

Mean birth weights (with standard deviation, minimum and maximum values) among different calves breeds, between seasons and between sexes are presented in Table 1. Overall, Vianze calves had the highest mean birth weight (26.6 kg) among the crossbreeds, while Mpwapwa breed calves had the lowest (22.6 kg). Calves born during the rainy season had higher birth weights than those born during the dry season, and male calves were born heavier than female calves.

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Table 1. Mean calf birth weights of Mpwapwa breed and its crosses born into the dry and rainy seasons from 2018 through to 2023, at a cattle farm of Tanzania Livestock Research Institute (TALIRI), Mpwapwa centre – Tanzania

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		N	Mean (kg)	Std. dev	Min.	Max.
Crossbreed	Chibamba	81	24.4	4.25	14	35.8
	Kikombo	61	25.7	3.31	18.7	33
	Matondwe	35	24.5	4.01	15.5	36
	Mpwapwa	344	22.6	3.94	13.5	34
	Vianze	64	26.6	5.06	18	42
Season	Dry season	395	23.4	4.17	13.5	39.2
	Rainy season	190	24.4	4.52	15.5	42
Sex	Male	304	24.5	4.44	14	42
	Female	281	22.9	4.02	13.5	39.2

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N= sample size, Std.dev = Standard deviation, Min. = Minimum weight, Max. = Maximum weight

Results showed that mean birth weights differed between seasons (F=4.88, *P*=.03). In addition, breeds differed in birth weights (F=17.33, *P*<.001), but there was no effect of interaction between season and breed (F=1.02, *P*=.39). Univariate comparison showed that the mean birth weight of calves born in dry season was lower compared to that of calves born in the rainy season (*P*=.04) (Table 2).

Table 2. Comparison of mean birth weights of calves born during the dry and rainy seasons from 2018 to 2023, at a cattle farm of Tanzania Livestock Research Institute (TALIRI), Mpwapwa centre – Tanzania

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	Mean (SD)	t	df
Birth weight of calves born during the dry season	23.4	-2.68*	348
Birth weight of calves born during the rainy season	24.4		

SD= Standard Deviation; t= t value, df = degrees of freedom

Pairwise comparisons between breeds showed that Chibamba calves had higher birth weights compared to Mpwapwa calves (*P*=.002), Vianze calves were heavier than Chibamba calves (*P*=.019); Kikombo calves were heavier than Mpwapwa calves (*P*<.001) and Vianze calves were heavier than Mpwapwa calves (*P*<.001) (Table 3).

Table 3. Pairwise comparisons of mean calf birth weights of Mpwapwa breed and its crosses born in dry and rainy seasons from 2018 to 2023, at a cattle farm of Tanzania Livestock Research Institute (TALIRI), Mpwapwa centre – Tanzania

Row mean – Column mean	Chibamba	Kikombo	Matondwe	Mpwapwa
Kikombo	1.27*			
Matondwe	0.0612	-1.21		
Mpwapwa	-1.88*	-3.15*	-1.94*	
Vianze	2.12*	0.846	2.05	3.99*

**Significant difference*

4. DISCUSSION

The results of this study have demonstrated a significant effect of seasonal mating on calf birth weights, with calf crops produced during the rainy season (December and February) having higher birth weights. This can be attributed to the differences in nutritional statuses of their mothers across the seasons. The results appear to suggest that cows/heifers mated during the rainy season (March – May mating season) were in a better plane of nutrition during their pregnancy. These animals spent most of their pregnancy time feeding on the leftovers of maize stover as well as hay which was supplemented in the dry season before calving. This presumably led to higher mean calf birth weight for the calves that were born in a subsequent rainy season. Feeding cattle maize stover even without supplementation has

been reported to increase daily cow live weight gain by 550g [14] since it contains high energy levels [15]. This has a positive implication on the mean calf birth weight because more energy supply in pregnant cattle is necessary in fulfilling nutritional body requirements and is also important in maternal tissue formation, fetal development, metabolism, maintenance and growth performance [16–18]. This was also supported by Malau-Aduli et al. [19] who observed a significant increase in kids' birth weight after pregnant does were supplemented with crop residues.

Maize crop residues account for almost 25% of the total feed energy suitable for ruminant livestock [20]. Its energy availability to ruminants is limited by a chemical association between lignin and structural cell wall carbohydrates for microbial fermentation [21]. Generally, it has 2.2 – 12.6% ash content, a high dry matter calorific value of 16.4 – 17.4 MJ kg^{-1} [15,22], high NDF (over 70%) and low in nitrogen (< 3% CP) than the minimum requirement of 7% CP which is necessary for optimum microbial activity in the rumen [23,24]. However, its chemical composition was reported to vary depending on the different morphological fractions of the corn plant, age of the growth and season variability [15,22,25,26]. For example Li et al [25] reported corn stover leaf blade had a CP content of 9.95% and the lowest NDF and ADF contents (62.1% and 31.1%, respectively) while stem rind had the lowest CP content of 1.9% and highest ADF and ADL contents (47.7% and 8.3% respectively) whereas ear husk had higher NDF content (82.7%) and lower ADL (3.6%) compared to other corn stover fractions.

On the other hand, calves that were born in the dry season between June and August had lower mean birth weights because before calving, groups of pregnant cattle were grazed entirely on the natural pastures in the period between December and May. This is a rainfall period in which re-growth occurs to most of the natural vegetation including pasture species which is has also become lushly with low dry matter that cannot sustain feeding requirements for the pregnant cattle. Moreover regeneration of pastures species in the semi-arid area is low due to low availability of phosphorous and nitrogen in the soil [27]. This makes pasture in semi-arid areas to have low productivity and nutritive value and tends to grow rapidly and quickly attain the highest quality which means livestock feeding remains high for a short period of wet season and low in the long dry season [28,29]. Furthermore, during the early stage of wet season between December and January termites become more active in the breakdown of the remaining organic matter and dried feed resources on the fields [30]. Additionally, fungi effects on the natural ecosystem and pastures were also reported also to reduce pasture biomass yield and quality [31] and therefore create further shortage of pastures for pregnant cattle. Inadequate availability of quality feed resources in the grazing areas between December and January is a major reason for low mean calf birth weight during the June to August calving season [32–34]. Moreover, it contributes to livestock illness, mortality cases, low production output and animal productivity [32,35].

Results of this study have also shown that calf crossbreeds, differed in birth weights, with higher birth weights in Mpwapwa crosses compared to Mpwapwa calves. *Bos taurus* breeds are mostly found in temperate countries and have high production potential but are poorly adapted to tropical harsh environment while *Bos indicus* breeds are widely found in tropics have low growth rates and production potential but are highly adapted to harsh environments [5]. Crossbreeding of indigenous cattle with exotic breeds has been used as a mojar strategy to improve milk production, growth rates and other production performances [36,37]. Therefore, crossbreeding of cattle by using superior breeding bulls with high genetic levels of *Bos taurus* and production potential has led to higher mean calf birth weight. This is also supported by Touchberry and Bereskin [38] in the Illinois crossing breeding project, when they observed an increase in calf birth weight by 4.3% after evaluation of breeding effect between Holstein and Guernsey cattle. Moreover, this similar observation was reported by Mendonca et al. [39] when they evaluated additive and heterosis effects on growth curves, total milk yield, calf weaning weight, predicted energy intake and cow efficiency of purebred and crossbred beef cows raised in the Southern Brazil. Also, Mendonca et al. [40] reported

similar findings when they examined breed additive and heterosis effects on carcass traits and characteristics of the meat from beef cows.

5. CONCLUSION

This study has shown influence of mating season on the calf birth weights, with calves born during the rainy season having higher birth weights, due to a better plane of nutrition of their mothers. Due to climatic changes and shortage of enough and quality pastures and other feed resources for ruminants in the semi arid environment of Tanzania, highly adapted and quality pastures for ruminants should be established, harvested, conserved and utilized in parallel with maize stover and other crop residues for sustainable livestock feeding practices. This is very important for sustainable livestock production and productivity in the semi arid areas especially in the period of rainy season between December and May for the pregnant cattle before calving season of June – August to opt for high mean calves' birth weight.

CONSENT

Not applicable

ETHICAL APPROVAL

Not applicable

REFERENCES

1. Kiwuwa GH, Kyomo ML. Milk Composition and Yield Characteristics of Mpwapwa Cattle. East African Agricultural and Forestry Journal. 1971;36: 290–295. doi:10.1080/00128325.1971.11662473

2. Syrstad O. Mpwapwa cattle: An Indo-Euro-African synthesis. Trop Anim Health Prod. 1990;22: 17–22. doi:10.1007/BF02243492

3. Katyega. Mpwapwa | Animal Genetics Training Resources. In: Animal Genetics Training Resource (AGTR) [Internet]. 1987 [cited 12 Oct 2023]. Available: http://agtr.ilri.cgiar.org/mpwapwa

4. Mabruck MM. Comparative Assessment of Productive and Reproductive Performances of Mpwapwa Breed Cattle and Its Crosses. 2022. Available: http://suaire.suanet.ac.tz/bitstream/handle/123456789/5035/MERCY%20MAXWELL%20MABRUCK.pdf?sequence=1&isAllowed=y

5. Manzi M, Rydhmer L, Ntawubizi M, Karege C, Strandberg E. Growth traits of crossbreds of Ankole with Brown Swiss, Holstein Friesian, Jersey, and Sahiwal cattle in Rwanda. Trop Anim Health Prod. 2018;50: 825–830. doi:10.1007/s11250-017-1501-7

6. FAO. Livestock keepers: guardians of biodiversity. Rome: Food and Agriculture Organization of the United Nations; 2009. Available: https://www.fao.org/3/i1034e/i1034e.pdf

7. Galina CS, Geffroy M. Dual-Purpose Cattle Raised in Tropical Conditions: What Are Their Shortcomings in Sound Productive and Reproductive Function? Animals. 2023;13: 2224. doi:10.3390/ani13132224

8. D.M. Komwihangilo, J.I. Mkonyi, D.F. Masao, E. Moto, A.M.O Mahiza, V. Mzava. Performance and challenges in the management of improved cattle in agro-pastoral systems of central tanzania. 1 May 2009 [cited 12 Oct 2023]. Available: http://www.lrrd.org/lrrd21/5/komw21075.htm

9. Chasama LG, Tungu BG. Socio-economic Values and Performance of Zebu Cattle Indigenous in Ukerewe and Bunda Districts of Tanzania. Huria: Journal of the Open University of Tanzania. 2017;24: 111–125. doi:10.4314/huria.v24i3

10. Msanga YN, Mwakilembe PL, Sendalo D. The indigenous cattle of the Southern Highlands of Tanzania: distinct phenotypic features, performance and uses. 1 Jul 2012 [cited 12 Oct 2023]. Available: http://www.lrrd.org/lrrd24/7/msan24110.htm

11. Ferrell C. Factors Influencing Fetal Growth and Birth Weight in Cattle. Roman L Hruska US Meat Animal Research Center. 1993. Available: https://digitalcommons.unl.edu/hruskareports/132

12. Holland MD, Odde KG. Factors affecting calf birth weight: A review. Theriogenology. 1992;38: 769–798. doi:10.1016/0093-691X(92)90155-K

13. Rahbar R, Abdullahpour R, Sefidmazgi AS. Effect of Calf Birth Weight on Milk Production of Holstein Dairy Cattle in Desert Climate. JABB. 2016;4: 65–70. doi:10.14269/2318-1265/jabb.v4n3p65-70

14. Tuturoong RAV, Malalantang SS, Moningkey SAE. Assessment of the nutritive value of corn stover and king grass in complete feed on Ongole steer calves productivity. Vet World. 2020;13: 801–806. doi:10.14202/vetworld.2020.801-806

15. Lizotte P-L, Savoie P, De Champlain A. Ash Content and Calorific Energy of Corn Stover Components in Eastern Canada. Energies. 2015;8: 4827–4838. doi:10.3390/en8064827

16. Chen H, Wang C, Huasai S, Chen A. Effect of prepartum dietary energy density on beef cow energy metabolites, and birth weight and antioxidative capabilities of neonatal calves. Sci Rep. 2022;12: 4828. doi:10.1038/s41598-022-08809-6

17. Institute of Medicine (IOM). Nutrition During Pregnancy: Part I, Weight Gain : Part II, Nutrient Supplements : Summary. National Academy Press; 1990. Available: https://books.google.co.tz/books/about/Nutrition_During_Pregnancy.html?id=tEMrAAAAYAAJ&redir_esc=y

18. Sguizzato ALL, Marcondes MI, Dijkstra J, Valadares Filho S de C, Campos MM, Machado FS, et al. Energy requirements for pregnant dairy cows. PLoS One. 2020;15: e0235619. doi:10.1371/journal.pone.0235619

19. Malau-Aduli B, Eduvie L, Lakpini C, Aduli Enoch Othniel Malau-Aduli. Crop-residue supplementation of pregnant does influences birth weight and weight gain of kids, daily milk yield but not the progesterone profile of Red Sokoto goats. Reproduction Nutrition Development. 2004;44: 111–121. doi:10.1051/rnd:2004022

20. Adebowale, E.A.,. Maize residues as ruminant feed resources in Nigeria. 1988 [cited 9 Oct 2023]. Available: https://www.fao.org/3/u8750t/u8750T0d.htm

21. Wattanaklang B, Abrar A, Cherdthong A. Nutritional Value of Fermented Maize Stover as Feed for Ruminant. JPS. 2016;5. doi:10.33230/JPS.5.1.2016.3919

22. Helsel ZR, Wedin WF. Direct combustion energy from crops and crop residues produced in Iowa. Energy in Agriculture. 1981;1: 317–329. doi:10.1016/0167-5826(81)90028-0

23. Juma HK, Abdulrazak SA, Muinga RW, Ambula MK. Effects of Supplementing Maize Stover With Clitoria, Gliricidia and Mucuna on Performance of Lactating Jersey Cows in Coastal Lowland Kenya. 2006. Available: https://www.redalyc.org/pdf/939/93960101.pdf

24. Woyengo TA, Gachuiri CK, Wahome RG, Mbugua PN. Effect of protein supplementation and urea treatment on utilization of maize stover by Red Maasai sheep. South African Journal of Animal Science. 2004;34: 23–30. doi:10.4314/sajas.v34i1.3806

25. Li HY, Xu L, Liu WJ, Fang MQ, Wang N. Assessment of the nutritive value of whole corn stover and its morphological fractions. Asian-Australas J Anim Sci. 2014;27: 194–200. doi:10.5713/ajas.2013.13446

26. Tolera A, Sundstøl F. Morphological fractions of maize stover harvested at different stages of grain maturity and nutritive value of different fractions of the stover. Animal Feed Science and Technology. 1999;81: 1–16. doi:10.1016/S0377-8401(99)00072-3

27. Menezes KMS, Silva DKA, Queiroz MAA, Félix WP, Yano-Melo AM. Arbuscular mycorrhizal fungal communities in buffelgrass pasture under intercropping and shading systems in Brazilian semiarid conditions. Agriculture, Ecosystems & Environment. 2016;230: 55–67. doi:10.1016/j.agee.2016.05.024

28. Abusuwar A, Ahmed E. Seasonal variability in nutritive value of ruminant diets under open grazing system in the semi-arid rangeland of Sudan (South Darfur State). ABJNA. 2010;1: 243–249. doi:10.5251/abjna.2010.1.3.243.249

29. Njau FBC, Lwelamira J, Hyandye C. Ruminant livestock production and quality of pastures in the communal grazing land of semi arid central Tanzania. 2013. Available: http://www.lrrd.org/lrrd25/8/Njau25146.htm

30. Figueirêdo RECRD, Vasconcellos A, Policarpo IS, Alves RRN. Edible and medicinal termites: a global overview. J Ethnobiology Ethnomedicine. 2015;11: 29. doi:10.1186/s13002-015-0016-4

31. Mlay JA, Kuwi SO, Maleko D, Mtengetic EJ. Incidences of fungal leaf spot disease in buffel grass (Cenchrus ciliaris) in some selected pasture farms in Tanzania. MSJ. 2022;4: 1–7. doi:10.31893/multiscience.2022015

32. Dauda A, Okon B, Joseph Henry A, Dauda Nggada J. Reproductive Performance and Management of Three Breeds of Cattle under Major Constraints in Extensive Management. Farm Anim Health Nutr. 2023;2: 30–34. doi:10.58803/fahn.v2i2.13

33. Hassan HM, Dubad AB, Muse MM, Ali AM, Ali BS. Assessment of Reproductive Efficiency and Herd Dynamics of Local Cattle Breeds in Benadir Region, Somalia. Adv Anim Vet Sci. 2020;8. doi:10.17582/journal.aavs/2020/8.10.1100.1108

34. Tolera A, Assefa G, Geleti D, Gizachew L, Mengistu A. Feed resources availability and quality. Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation. 2012; 37–46.

35. White TCR. The importance of a relative shortage of food in animal ecology. Oecologia. 1978;33: 71–86. doi:10.1007/BF00376997

36. Bwire JMN, Wiktorsson H. Effect of Supplementary Feeding Strategies on the Performance of Stall Fed Dual-purpose Dairy Cows Fed Grass Hay-based Diets. Asian Australas J Anim Sci. 2003;16: 359–367. doi:10.5713/ajas.2003.359

37. Chawala AR, Banos G, Komwihangilo DM, Peters A, Chagunda MGG. Phenotypic and genetic parameters for selected production and reproduction traits of Mpwapwa cattle in low-input production systems. SA J An Sci. 2017;47: 307. doi:10.4314/sajas.v47i3.7

38. Touchberry RW, Bereskin B. Crossbreeding Dairy Cattle. I. Some Effects of Crossbreeding on the Birth Weight and Gestation Period of Dairy Cattle. Journal of Dairy Science. 1966;49: 287–300. doi:10.3168/jds.S0022-0302(66)87851-7

39. Mendonça FS, MacNeil MD, Leal WS, Azambuja RCC, Rodrigues PF, Cardoso FF. Crossbreeding effects on growth and efficiency in beef cow–calf systems: evaluation of Angus, Caracu, Hereford and Nelore breed direct, maternal and heterosis effects. Translational Animal Science. 2019;3: 1286–1295. doi:10.1093/tas/txz096

40. Mendonça FS, MacNeil MD, Nalerio E, Cardoso LL, Giongo C, Cardoso FF. Breed direct, maternal and heteros is effects due to Angus, Caracu, Hereford and Nelore on carcass and meat quality traits of cull cows. Livestock Science. 2021;243: 104374. doi:10.1016/j.livsci.2020.104374