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Prevalence of endo- and ectoparasites and their related epidemiology during the rainy season: Evaluation for cattle breed selection in a semi-arid wildlife zone

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ABSTRACT

Cattle health in wildlife zones is often compromised by parasitic infestations. This study aimed to assess the prevalence and epidemiology of ecto- and endoparasites among cattle inhabiting a semi-arid wildlife zone, examining the influence of age, breed, and tolerance. A total of 320 cattle were surveyed, and a representative sample of 36 animals (using random selection methods) from different age groups (calves, weaners, adults) and breeds (Brahman, Angus, Beef master) were chosen for detailed parasite analysis. Parasite identification was conducted with veterinary assistance and supplemented by relevant literature. A high prevalence of ectoparasites was observed, with four prominent hard tick species identified which included the Rhipicephalus (Boophilus) decloratus (27.44 ticks per animal), Rhipicephalus appendiculatus (10.50), Amblyomma variegatum (0.83), and Hyalomma spp (0.44). Additionally, internal parasites were identified including Fasciola spp (0.14), Fasciola eggs (1.89), Trematode eggs (2.81), Strongyle eggs (2.50), and Ascaris lumbricoides (0.14). Weaners exhibited a higher susceptibility to parasitic burdens, while the Beef master breed displayed a significantly low parasite count compared to other breeds. Brahman and Angus breeds demonstrated tolerance to parasites, with minimal recorded mortality. Although a direct correlation between wildlife and cattle diseases was not established, the study investigated potential shared parasites with commonly encountered wildlife species in the zone. These findings highlight the importance of targeted parasite control programs, particularly for weaners, to minimize health risks and enhance herd well-being in wildlife zones. Implementing parasite management strategies tailored to breed-specific tolerances and age groups is crucial for optimal cattle health and productivity in such environment.

Introduction

With a current inventory of 17 billion farm animals worldwide, livestock production is expected to increase, particularly in developing countries (Latino *et al.*, 2020). This increase has been necessitated by an increase in meat and milk consumption caused by the increase in the global human population which has been recorded to be at 1.1% each year (Machovina *et al.*, 2015). The total meat and milk consumption is expected to rise to 450 and 880 million tons respectively towards the year 2050 (FAO, 2018), and half of these will be consumed in developing countries, due to population growth, urbanization, and rising incomes (Machovina *et al.*, 2015). Population growth and urbanization have resultantly pushed humans into wildlife territory, evidenced by the current human-wildlife conflicts and zoonoses (Gadaga *et al.*, 2015; Mekonen, 2020). The location of livestock within wildlife territories also poses a further threat since genetic differences will place the superior wildlife as carriers and inferior livestock as victims (Ferran *et al.*, 2021). Livestock diseases adversely affect animal production worldwide (Agbeja *et al.*, 2021). Parasitic infection is a major health scare in the world, and, it is reported that these infections affect the health of millions of people and animals, causing huge economic losses in livestock farming (Abebe *et al.*,

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2018, Sado *et al*., 2022). Parasites are organisms that live on or in other organisms such as animals to survive (Fracasso, 2022). The parasites cause major losses in cattle production (Rashid *et al*., 2019), a major enterprise in the provision of meat and milk. An estimated $93.1 million is lost to parasite infestation, mainly due to treatment costs and production loss (Jaja and Wanga-Ungeviwa, 2022). A recent Ugandan study reported a loss of USD 9992.4 due to fasciolosis between 2015 to 2020 (Opio *et al*., 2021). Consequences of parasitic infection include reduced feed intake, reduced immunity, lower fertility, a reduction in milk production, an increase in treatment expenses, and death in critical infections (Rashid *et al*., 2019). In general, parasites are the most numerous animals on earth (Abebe *et al*, 2018).

Parasites are categorized into internal and external parasites. The external or ectoparasites are the organisms that live on and feed off their host animal; these include flies, lice, ticks, and mites. causing serious diseases resulting in skin irritation and animal stress (Charlier *et al*, 2020). On the other hand, internal or endo-parasites are organisms that invade the body of the host, occupying the digestive tract or body cavities or living within body organs, blood tissues, or cells (Christaki, 2020). The intestinal tract harbors a variety of helminthic parasites, including nematodes, cestodes which are localized to the small intestine, and trematodes, specifically the liver fluke Additionally, protozoan parasites can be found in the lower intestinal tract (Zvinorova *et al*., 2016).

Economically important genera of tick-borne prokaryotic and eukaryotic haemo-parasites that affect cattle in communal areas include rickettsia *Anaplasma* and *Ehrlichia* (*Cowdria*), and the protozoan parasites, *Babesia* and *Theileria* (Guo *et al*., 2019; Chatanga and Nakao, 2022). Cattle visitation to areas that possess nutrient-rich forage can increase parasitic infestations. According to Coop and Holmes (1996), animals ultimately prefer protein-rich forages to counter production losses due to parasitism. With the hope of improving livestock health and increasing productivity, many managers have implemented parasite treatments (Morgan *et al*., 2022).

This study, therefore, aims to identify possible risk factors for parasite infections, taking breed and age of cattle into particular consideration. Additionally, it looks for breeds that are resistant to parasites and suitable for these kinds of environments. Through a thorough analysis of parasite distribution and prevalence, this study seeks to offer important information for implementation in current practical aspects of cattle production and future research to lessen parasitic hazards in wildlife habitats.

Materials and Methods

Ethical Considerations

This study was done upon ethical clearance from Lupane State University and in consultation with the Veterinary Services Department in Zimbabwe.

Study site

The study was conducted at Merry Ellen Farm (Figure 1) in Bubi district which is under agro-ecological region 4. The farm is located 80 km north of Bulawayo. The area is situated in the low-lying north and south of Zimbabwe. The area receives an annual rainfall of 450-650mm. It is characterized by severe dry spells and frequent seasonal droughts.

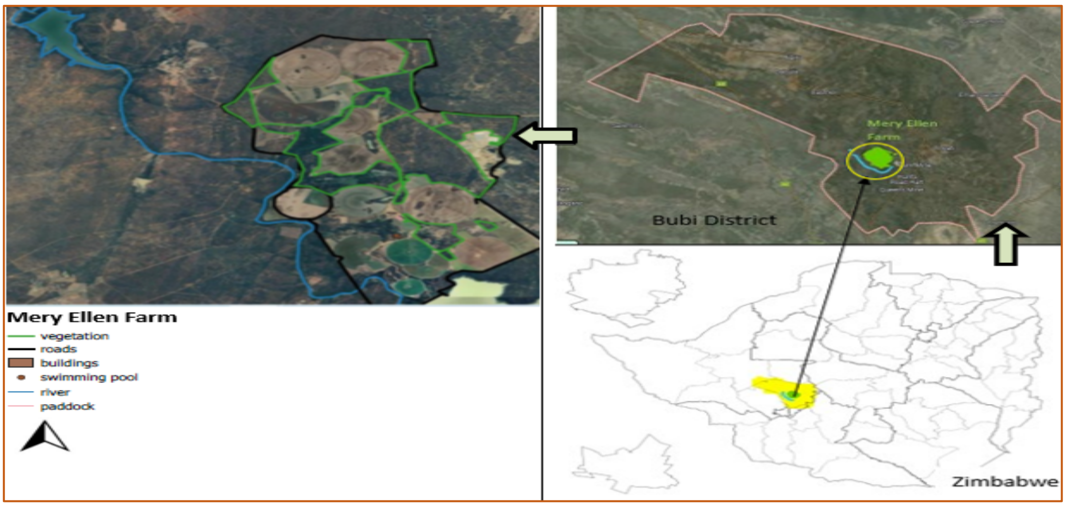

Figure 1. The map of research site showing the Mery Ellen Farm

Soils are sandy loams derived from granite rocks. The area is suitable for livestock production and wildlife management (Chaptterjee, and Nair, 2018). The main enterprises at the farm include the crop department (which grows wheat, maize, soya beans, and Giant Rhodes grass) and the animal department (rears impala, kudus, bushbucks, monkeys, snakes, and cattle). Surrounding areas inhabit hyenas, guinea fowl, and buffalo. Within the animal department, activities include feed formulations, feeding, weighing, dosing, dipping, vaccinations, and silage-making. The total farm area is 1400 hectares. There is Dola Wildlife reserve which is located a few kilometers from the Farm.

Management of wild animals on the farm

Wild animals are reared in the bushy area of the farm. The wild animals are kept for sale and meat. Every month, animals are killed and the meat is cooked for workers. Supplementary feeding in the form of nutritional blocks is done in a cleared area in the bush where animals are likely to graze. The movement of wild animals is restricted, as to prevent the transmission of diseases to livestock. The security fences that surround livestock paddocks restrict the entry of animals into the cattle paddocks.

Management of cattle on the farm

The breeds kept on the farm include Brahman, Beef master, and Angus (Red and White). The dominating breed is the Beef master. The average body weight for calves (75kg), weaners (220kg), cows (390kg), and bulls (500kg).

The dosing of cattle was done once a month using Flukazole C, which primarily contains amitraz, an effective tick-killing agent that interferes with tick nervous systems, leading to their demise. Additionally, private dipping with Decatix and Triatix, products from Coopers, was conducted once a week during summer and once in two weeks during winter using a spray race. These products combine amitraz with cypermethrin, a synthetic pyrethroid insecticide, providing a broad-spectrum approach to tick control, thereby enhancing the efficacy of the dipping solution against various tick species. Open wounds were treated with oxy-tetracycline (OTC) spray, iodized antiseptic, agricultural lime, and Stockholm tar to reduce inflammation.

Any dead animal was taken to the slaughter area for dissection. All body parts were inspected; exterior and interior body condition were scored. The condemned parts were sampled and transported to the veterinary center for diagnosis. The carcass of an animal was buried in the bushy area away from other animal facilities.

Blocking was done using Oxy-tetracycline long-acting antibiotic which was administered subcutaneously in the ratio of 10mls for adult cattle and 5mls for calves. The cattle were vaccinated against lumpy skin disease, contagious abortion, and black leg. Prondistar, a vaccine for the prevention against Anthrax, Blackleg, and Botulism, was given to mature cattle at a recommended dosage of 2ml per animal. The brucella s19 vaccine was only applied to heifers for all breeds of cattle.

Study design

A systematic study was done, following a Randomized Complete Block Design (RCBD). A randomly selected number of cattle was subdivided into three age groups; calves (0-3) months, weaners (6-10) months, and cows and bulls (24-36) months. Blocking was done according to age and breed.

Sampling Procedure

From a total population of 320 cattle at Merry Ellen Farm, a group of 80 cattle was randomly selected using stratified random sampling to minimize congestion during selection. The cattle were stratified by age and breed, with calves (n=20), weaners (n=20), cows (n=20), and bulls (n=20) included. For calves and weaners, the selected breeds were purebred Beefmaster, hybrid Brahman, and hybrid Angus. For older cows and bulls, the selected breeds were purebred Beefmaster, Brahman, and Angus. A target of 12 animals per stratum was chosen to equally represent breed and sex. Within each stratum of 12 animals, four were purebred Beefmaster, four were hybrid Brahman, and four were hybrid Angus. Each breed group of four included two males and two females. A sample size of 36 animals (12 animals/stratum x 3 strata) was deemed manageable considering they were collected and analyzed three times a week. Additionally, internal parasites of any animal that died on the farm were examined through postmortem evaluation.

Treatment of samples

Table 1. Grouping system of experimental units

Group name	Sample type of animals
Group Alpha	The group was made up of an experimental sample of 36 animals selected from the population
Group Beta	Group made up of dead animals that were analyzed in postmortem

The collection of samples for analysis was done in two groups, the sampled group that consisted of 36 animals and the group of dead animals that were used in the postmortem. The groups were designated as alpha and beta (Table 1).

Sample collection

The samples for Group Alpha were collected from the live cattle and involved the collection of fecal samples, blood smears, and ticks. The samples were collected for a period of 21 weeks, from November to March 2021. The fresh fecal samples were collected soon after the cattle dropped the feces, of which 200g fecal sample was collected each time and kept in a clean container, then, labeled and kept in an ice box. Thin blood smears were collected from the cattle's ear vein. One drop of blood was placed on a clean glass slide and spread by another glass slide, air dried, and fixed in absolute methanol for about 3 to 4 min. The slides were then labeled and kept in a slide box. These samples were taken to the veterinary center for analysis (Table 2). The veterinary department provided information on the sampling procedures. The ticks were collected from the predilection sites of different animal parts such as briskets, dewlap, perineal region, udder, inner legs, eyes, and tail. All collected ticks were preserved in 70% glycerol (alcohol) and labeled with the number including the date, the host, and ultimately the location. For the three groups of cattle (calves, weaners, cows, and bulls) being studied, the samples were collected at three-week intervals. Veterinary personnel then aided in identifying the collected ticks using a guide (Table 3)

Table 2. Key for identification of internal parasites

Feature	Description
Shape	Body elongation, body form i.e. cylindrical or segmentation
Head end	Presence of suckers and hooks
Alimentary canal	Presence of the alimentary canal, completeness of the alimentary canal, and the presence of the anus
Body cavity	Presence of body cavity
Body covering	The hardness and form of the body covering
Digestive tube	Termination of the digestive tube

The table shows key features to help identify internal parasites as defined by Studocu, (2022).

For Group Beta, samples were collected through post-mortem examination of deceased animals. This involved inspecting the physical appearance of internal organs. Condemned organ tissues were collected in sterile containers and transported immediately to the veterinary center for analysis. The veterinary department guided sampling techniques and parasite identification (Table 2). Parasites were collected from internal organs, body parts, and feces of each deceased animal. All collected parasites were preserved in 70% glycerol (alcohol) and labeled with a number, date, host information, and location, following the same protocol used for Group Alpha samples. Additionally, 200-gram fecal samples were collected in clean containers, labeled, and stored in an icebox for analysis. This sample size was chosen to minimize the waste of analysis reagents while still providing conclusive results.

The collected fecal samples were examined using the floatation method and sedimentation technique as described by the methods of Graham and Williams, (2019). The number of eggs and oocytes per gram of feces was determined according to the following equation;

Eggs per gram (EPG)= (Number of eggs) in the two chambers x 100)/ 2

Blood smears

The thin blood smears were collected from the ear vein of the cattle and the drop of blood was taken on a clean slide. The slides were given labels containing information on the animal identification number, breed, age, and date of collection. In the laboratory, the smears were stained in 5% Giemsa's stain for 45 min and washed off with water thereafter. The stained smears were observed under a light microscope at a magnification of x1000. If the blood contains the parasite, it is said to be intracellular (Babesia, Anaplasma, and Theileria) or extracellular organisms (Trypanosomes) (Eberhard and Lammie, 2020).

Table 3. The key to identifying ticks

Feature	Description
Eye Palps(P)	The form and size of eye palps
Basis Capitulum(B)	The shape of the capitulum and presence of spurs.
Scutum(Sc)	The ornamental behavior of the scutum.
Anal groove(A)	Form of Anal groove
Festoons(F)	The presence of festoons and appearance of coalesced level.
Spiracular plate(Sp)	The structure of the protrusion.
Ventral Plates(Ad)	The presence of ventral plates
Legs	The appearance of legs

Presence of key features for the identification of ticks as defined by Ikpeze *et al*., (2011).

Data analysis

The data were analyzed using GraphPad Prism version 8.0.1 and expressed as mean ± standard deviation. Significant differences between groups were determined using two-way ANOVA, followed by Tukey's multiple comparisons, for comparing all age groups and all groups of breeds. A non-parametric t-test was used to determine significant differences between means for the two groups. Only values of $p < 0.05$ were accepted to indicate statistical differences (Mitteer *et al*., 2020).

Results

Group alpha

The research focuses on the prevalence of parasites within three age groups; calves, weaners, and, mature cattle (cows and bulls), every parasite found, has been summarized and averaged under every parasitic classification. The overall parasitic prevalence was calculated per age group and breed and demonstrated using bar charts and tables.

Total external parasites were determined (Table 4), and their prevalence according to the average numbers obtained for each identified parasite. Herds were found to be infested with hard ticks. Four different tick species were identified and these identified tick species were; *Rhipicephalus boophilus decloratus*, *Amblyomma variegatum*, *Hyalomma spp*, and *Rhipicephalus appendiculatus*. The most abundant tick species were *Rhipicephalus boophilus decloratus* and *Rhipicephalus appendiculatus* with an average of 27.44 and 10.50 ticks per animal respectively. Other species found in decreasing order of abundance were A. *Variegatum spp* (0.83) and Hyalomma (0.44).

The study identified a range of internal parasites, including trematodes (Fasciola spp. and trematode eggs) and nematodes (Ascaris lumbricoides and strongyle eggs). Trematode eggs were the most prevalent, with an average of 2.81 eggs per animal. Strongyle eggs followed at 2.50 eggs/animal, while Fasciola eggs and Ascaris lumbricoides were less common (1.89 eggs/animal and 0.14 adult worms/animal, respectively). Anaplasma spp., a blood parasite, was also detected with an average of 1.11 bacteria per ml of blood.

The susceptibility of different age groups to parasite infection was determined with comparisons done among the age groups. Weaners showed a high prevalence of parasites with an average of 7.35 followed by Cows and bulls with an average of 4.23 and lastly, Calves had the least number of parasites showing an average of 3.11 parasites (Figure 2).

A comparison of the prevalence of each parasite species against breed of cattle was done (Table 5). The most prevalent external parasite was *R. Boophilus* spp with an overall mean of 27.44 and high means recorded across all breeds of cattle. The least prevalent external parasite was recorded from *Hyalomma spp* with a mean of 0.44.

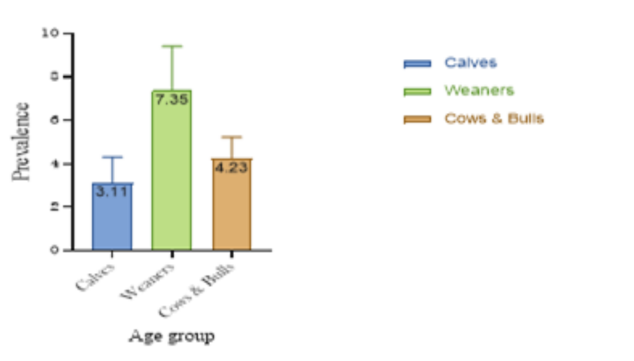

Figure 2. Susceptibility to parasites for each age group.

The highest prevalence of internal parasites was recorded from the trematode's eggs with an overall mean of 2.81 and high means were recorded across all the breeds. Fasciola spp had the lowest prevalence with an overall mean of 0.14. The parasite species (*R. boophilus spp, Hyalomma spp,* R *Appendiculatus spp*, Trematodes eggs, Strongyle eggs, *Fasciola spp*, and *Ascaris Lumbricoides*) were significant ($p<0.05$) in terms of prevalence.

Statistics on the prevalence of parasites by interaction within age have been represented in Figure 3. The Weaners showed the highest prevalence within the entire breeds with Calves having the least prevalence recorded across all the breeds. The highest prevalence of parasites was recorded from the Brahman with an average of 31.80. The lowest prevalence of parasites was recorded from the Beef master with an average of 11.10 parasites per animal.

Group beta

The research also focused on the impacts of the parasites within three age groups; calves, weaners, and, mature cattle (cows and bulls). During the study period, the animals that died were recorded together with postmortem findings. The identified causes of death were infection and non-infection-related. The infection-related diseases included; Heartwater, Jaundice, Sweating sickness, Anaplasmosis, Pneumonia, 3 Day stiff sickness, and Lumpy skin. The non-infectious causes were; Difficult birth and Plastic consumption.

Table 4. Comparison of each parasite species against the age group of cattle

	Parasites	Age			Mean	SEM	P-value	Significance
		Calves	Weaners	Cows and Bulls				
Endoparasites	Trematode eggs	1.67±0.51 [b]	3.58±0.65 [a]	3.17±0.81 [a]	2.81	0.581	0.0404	*
	Strongyle eggs	1.00±0.28	3.50±0.60	3.00±0.65	2.50	0.764	0.0820	ns
	Fasciola eggs	0.83±0.30	1.92±0.61	2.92±0.70	1.89	0.604	0.0882	ns
	Ascaris Lumbricoides	0.58±0.23	1.42±0.31	1.83±0.47	1.28	0.368	0.0737	ns
	Fasciola spp	0.08±0.08	0.25±0.13	0.08±0.08	0.14	0.057	0.1296	ns
	Anaplasma spp	0.58±0.43	1.83±0.86	1.00±0.47	1.14	0.367	0.0902	ns
Ectoparasites	*R. Boophilus* spp.	22.42±3.11	48.33±4.44	11.58±1.20	27.44	10.902	0.1282	ns
	A. Variegatum spp.	0.67±0.22	1.25±0.28	0.58±0.19	0.83	0.210	0.0579	ns
	Hyalomma spp.	0.33±0.19	0.83±0.34	0.17±0.11	0.44	0.199	0.1567	ns
	R *Appendiculatus* spp.	2.92±0.87	10.58±2.25	18.00±2.89	10.50	4.353	0.1374	ns

Means are +/- standard deviation. Means within a row followed by a different superscript are significantly different ($P < 0.05$), ns-not significant, *-significant. SEM-standard error of measurement

Table 5. Comparison of each parasite species against the breed of cattle

	Parasites	BREED			Mean	SEM	P value	Significance
		Beef master	Brahman	Angus				
Endoparasites	Trematode eggs	3.33±1.11[a]	3.08±0.98[a]	2.00±0.33[b]	2.80	0.408	0.0205	*
	Strongyle eggs	3.00±0.21[a]	2.33±1.23[b]	2.17±0.34[b]	2.50	0.254	0.0102	*
	Fasciola egg	1.75±0.70	2.75±0.57	1.17±1.00	1.89	0.461	0.0548	ns
	Ascaris lumbricoides	1.42±0.29[a]	1.58±0.45[a]	0.83±0.60[b]	1.28	0.228	0.0305	*
	Fasciola spp.	0.17±0.09[a]	0.08±0.04[b]	0.17±0.10[a]	0.14	0.030	0.0430	*
	Anaplasma spp.	0.92±0.26	1.92±0.34	0.50±0.10	1.11	0.421	0.1183	ns
Ectoparasites	*R. Boophilus* spp.	21.75±3.11[b]	31.25±1.20[a]	29.33±4.02[a]	27.44	2.900	0.0110	*
	A.variegatum spp.	1.25±0.22	0.67±0.14	0.58±0.41	0.83	0.210	0.0580	ns
	Hyalomma spp.	0.58±0.11[a]	0.42±0.23[a]	0.33±0.21[b]	0.44	0.073	0.0261	*
	R. *Appendiculutus* spp.	8.00±2.88[c]	8.92±0.78[b]	10.25±1.29[a]	9.06	0.653	0.0052	**

Means are +/- standard deviation. Means within a row followed by a different superscript are significantly different ($P < 0.05$), ns-not significant, *-significant. SEM-standard error of measurement

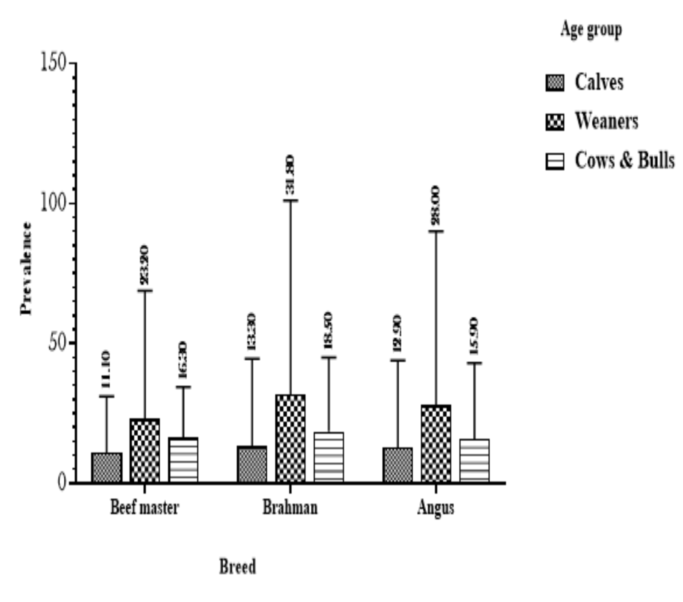

Figure 3: Prevalence of parasites with age and breed

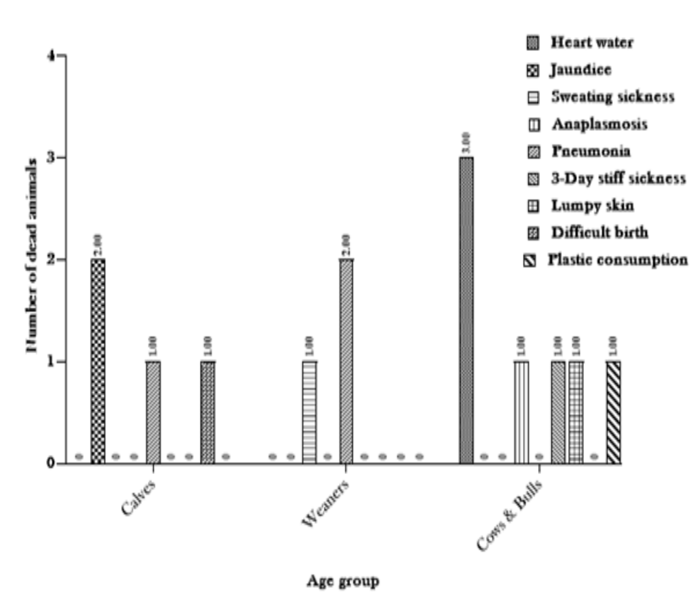

Figure 4: Causes of cattle mortality by age group

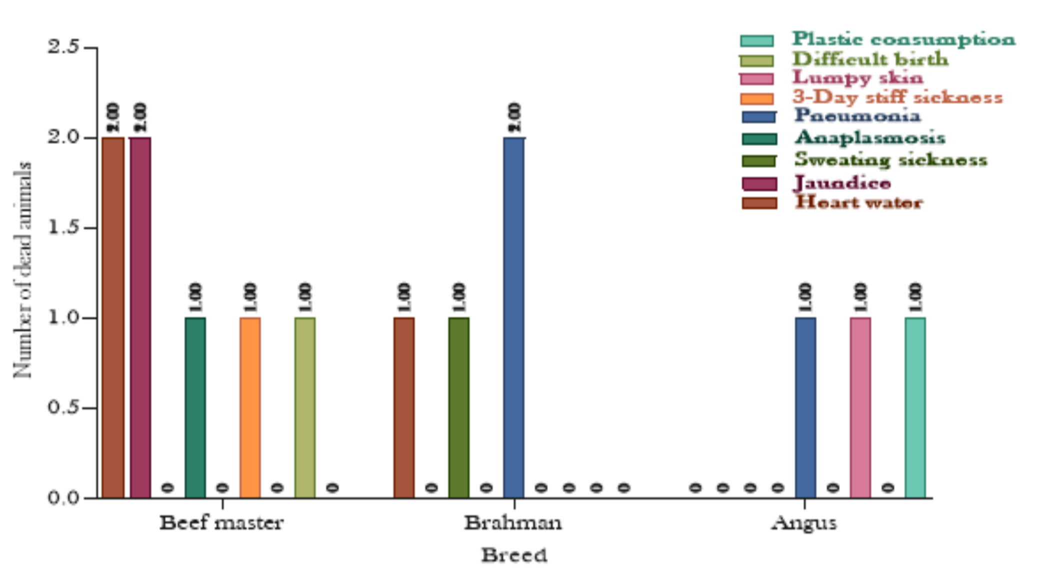

Figure 5: Causes of cattle mortality by breed

Disease identification for each age group was done (Figure 4). The Cows and Bulls recorded the highest number of diseases amongst all age groups and mainly died from Heartwater, Anaplasmosis, 3-day stiff sickness, Lumpy skin, and also through consumption of plastic.

The highest number of deaths recorded were due to Heartwater. The calves' mortality was due to Jaundice, Pneumonia, and Difficult birth. The highest number of recorded deaths were from Jaundice. The weaners were mainly found dying from Pneumonia and sweating sickness. The highest number of deaths and several diseases recorded were from the Beef master breed. The Beef master suffered from diseases that included Heartwater, Jaundice, Sweating sickness, and Anaplasmosis. The other cause of death was due to a difficult birth. The Brahman suffered from the following diseases; Heartwater, Sweating sickness, and Pneumonia. The highest number of deaths recorded in Brahman was due to Pneumonia. Angus mainly died due to Sweating sickness, Lumpy skin, and Plastic consumption (Figure 5).

Discussion

During the rainy season, high temperatures and moisture are a conducive environment for the development and survival of infective larvae on plants. These conditions result in increased availability of infective larvae on pastures, hence the chances of cattle picking up infective stages of the parasites whilst grazing become high, leading to a buildup of high worm burdens in the host. This can lead to an increase in fecal egg count (FEC) with peaks between February and March which declines during late autumn to early spring (May to September). The decline in FECs is due to a lack of rainfall and, to some extent, lower temperatures. This observation indicates that rainfall and temperatures play a significant role in the epidemiology of parasites in animal populations (Lobes *et al.*, 2022).

In the study, the herds were found to be infested with hard ticks, the most abundant tick species were *Rhipicephalus boophilus decloratus* and *Rhipicephalus appendiculatus*. Other species found in decreasing order of abundance were Amblyoma variegatum and Hyalomma. This is in agreement with a study done by Onu and Shiferaw (2013), in the Bench Maji zone, Southwest Ethiopia, who found the most prevalent species being the *Boophilus decoloratus* (8%), *Amblyoma variegatum* (4.7%) and *Amblyoma coherens* (4.2%). The *Rhipicephalus boophilus decloratus* is the most abundant species as indicated in the previous studies (Onu and Shiferaw, 2013) as well as in the current study because it is said to have a rapid displacement during favorable conditions. Interestingly, hard ticks **(**Rhipicephalus spp., Amblyomma spp., Hyalomma spp.) can infest a variety of wild mammals, including deer, antelope, rodents, and carnivores (Springer *et al.*, 2020). Therefore, wildlife could have served as hosts for these ticks, contributing to tick burdens in cattle.

Rhipicephalus boophilus decloratus is also said to have a reproductive cycle that is hardly destructed by preventative interferences done by farmers (Tonnesen *et al.*, 2004). Some species of ticks including Hyalomma showed lower prevalence during the study because they tend to attach in hidden places like tail brushes and under armpits, therefore, they can be easily missed during sampling. This is in agreement with Spickett *et al.* (2011), who observed that the tendency for adults to attach preferentially in the tail switch of cattle may explain why *Hyalomma truncatum* was not collected during the study.

The differences in tick prevalence and species distribution were influenced by differences in vegetation composition and cover, humidity, temperature, and annual rainfall as highlighted by Abdul *et al.* (2017) who indicated that parasitism is influenced by location and climate. During the study, it was found that the number of ticks increased as the summer season progressed with the highest number of ticks being collected in February and March. This may be due to environmental changes that occur during the rainy season when a peak level is reached. This is in agreement with the study by Jehan *et al.* (2020), who indicated that accelerated tick proliferation usually occurs when environmental temperatures and humidity are high.

The highest prevalence was recorded from the trematode since the highest number of *Fasciola spp* and both the *Fasciola spp* eggs were recorded. During the rainy season, there are relatively high temperatures accompanied by a humid atmosphere, this is suspected to have made trematodes have a high prevalence. This is in agreement with Pfukenyi and Mukaratirwa (2004), who observed that *Fasciola spp* are the most prevalent trematode found in cattle.

The most prevalent nematodes were the Strongyle eggs as compared to *Ascaris lumbricoids*. This is in agreement with Squire *et al*, (2019), who highlighted that Strongyle are usually in abundance while the *Ascaris spp* are usually less prevalent. The most prevalent blood parasite was the *Anaplasma species* and it was the only identified bloody parasite. This may be due to that the blood parasite cannot develop resistance to anthelmintic drugs.

The study shows that there is a significant difference in parasitism between the age groups, with Weaners having the highest parasitic infestation, followed by Cows and Bulls, and lastly Calves. This indicates that Calves are least affected by the parasites when compared to weaners. The reason is that calves do not graze full time on the pasture and as well they get the immunity boost through suckling colostrum from their dams (Byaruhanga *et al.*, 2015). This is in agreement with another study by Nyangiwe *et al.* (2023), who observed that the lower parasite infections in the calves could be attributed to some form of innate protection that declines with age. One study by Vande *et al.* (2018), also further explains the existence of lower tick loads in calves as a result of continuous selective grooming of the calves by their respective dams. The Calves and, Cows and Bulls did not have a significant difference meaning that their susceptibility to infections by parasites was similar.

The study also showed a high prevalence of parasites at the weaning stage. This may be due to those weaners being separated from their mothers and the only way to feed is through grazing. The Weaners are found to be energetic, drifting into areas close to wildlife, and can graze for long hours as well; this can increase the chances of infestation by parasites hence their uniquely high prevalence of parasitism observed. This scenario of being energetic and grazing for longer periods is not pronounced in an aged animal. This explains the lower parasitism observed in Cows and Bulls. However, Swai *et al.* (2006) argue that Cows and Bulls should have more parasitic infestations, especially the ectoparasites because older animals have a larger surface area predisposing them to higher tick infestations than younger animals.

The Trematodes and Nematodes showed the lowest prevalence in the calves compared to other age groups, with the *Anaplasma spp* having the least prevalence recorded across all age groups. Bandyopadhyay *et al.* (2010) suggest that the highest prevalence of these parasite species could be explained by the environment in which the cattle were being reared, and also by poor animal management. Were it not for the controlled movement of wildlife, the prevalence could be higher since wildlife can act as reservoir hosts for these parasites, contributing to transmission risk for cattle sharing grazing areas. The cows and bulls succumbed to being reared in mixed crop-livestock systems, resulting in high rates of parasitic infection due to the possibility of re-infection in contaminated pastures (Springer *et al.*, 2020).

No significant difference among the breeds was obtained when comparing parasitism among the three breeds. Across all breeds, there was generally a slight difference with each breed recorded. The beef master breed recorded a lower prevalence of parasites, despite the low prevalence of parasites observed in this breed; it had high mortality due to several diseases linked to parasites. Since the Beef master shows high mortality at a lower prevalence of parasites it simply implies that it is vulnerable and susceptible to infections with low survival rates, this may be due to less adaptability to climatic conditions. Lasater (2020), argues that beef master cattle are hardy therefore they can withstand a wide range of temperatures and humidity enabling them to become less prone to insects and parasites.

Brahman recorded the highest prevalence of parasites across all the breeds, despite having Angus closely following, but showed minimum mortality from parasite-related diseases. This is in agreement with research studies (Rashid and Hoque, 2022), which observed a high prevalence of gastrointestinal parasites in Brahman cattle of Bangladesh. Brahman and Angus seem to show a high level of disease resistance and resilience amongst the breeds due to their minimum mortality recorded. High disease resistance and resilience in these breeds might be due to their hardy nature, hence ease of adaptation. This is in agreement with Dikmen *et al.* (2018), who found that Brahman cattle exhibit a superior immunological memory; as well they show a stronger immune response when challenged by diseases and the Brahman's protein metabolism can focus more on protein synthesis through the production of more white blood cells and antibodies that can fight the parasitic infection. Byaruhanga *et al.* (2016), argue that non-immune Brahman cattle can become infected with parasites but clinical diseases and deaths are not common.

A firm assessment of the causes of cattle mortality within the stipulated period of study unveiled the causes of deaths as resulting from mainly ticks and insects facilitated viral and microbial infections. The most fatal diseases included Pneumonia a bovine respiratory disease caused by a combination of viruses and bacteria, Jaundice a hemolytic bacterial disease usually transmitted through ticks and Heartwater a tick bone (specifically *Amblyoma hebraeum*) disease caused by a bacterium *Cowdria ruminantium* (Deem, 2008).

It was found that Jaundice and Pneumonia were dominating in Calves and Weaners, whilst Heart water only killed Cows and Bulls. Jaundice and Pneumonia were found to predominate in the young stock because they are prone to be affected by bacterial microfloral imbalance in the body, which is usually caused by the spontaneous increase of the bacterium like hemolytic Clostridium spp, other bacteria, and viruses that break down blood cell components (McSherry *et al.*, 1984).

Heartwater seemingly affects aged cattle because their immune system is found to be compromised since it is said that the immune system effectiveness of animals decreases with age (Burns, 2004) as well the old animals are found to have a large surface area and are less energetic increasing chances of attachment of the heart water transmitting tick *Amblyoma hebraeum* are majorly the only causalities succumbing to death from Heartwater. According to Spickett *et al.* (2011), heartwater is the most important tick-borne disease; its importance is emphasized by several livestock mortalities as well as the decrease in livestock production.

Conclusions

Our findings underscore the role of breed selection in determining parasite resilience. Beef master was identified to be the most resilient against parasites but with high mortality due to disease-linked parasites. In contrast, Brahman and Angus had a high level of disease resistance and resilience due to their minimum mortality recorded. The weaners were found to be the most susceptible to parasites. Based on this current knowledge about the epidemiology of parasites in semi-arid regions, preventive treatment strategies can be formulated with an improved factor of good timing and choice of breed. It is important to understand the different life cycles of these different types of parasites as well as the efficacy of products used to treat the parasite species. Our investigation revealed that rainfall and temperature exerted significant influences on parasite burdens, while the presence of wildlife emerged as another critical factor warranting further exploration in subsequent studies. These insights, coupled with the identification of weaners as the most susceptible age group, furnish invaluable guidance for crafting targeted parasite control strategies. Practical applications of these findings include implementing strategic deworming programs tailored to parasite life cycles and the varying susceptibility of different breeds, with a focus on vulnerable groups like weaners, which can enhance treatment efficacy. Secondly, tailoring anthelmintic treatments based on the specific parasite species prevalent in the region will optimize parasite control outcomes, as is with the case of semi-arid wildlife zone where hard ticks were deemed highly prevalent.

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