

## The Reasons, Pattern and Control of Goat Mortality Under Semi-Arid Tropical Condition in Northern Tanzania

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**Received:** June 15, 2020; **Published:** August 05, 2020

### Abstract

This observational study was designed to inspect various reasons and pattern of mortality cases in meat goat breed types nurtured under farm breeding conditions. Mortality data of 513 goats died between 2005 and 2017 was summarized from the available animal health records. The data consisted of 153 Pare White (PW), 76 Sonjo Red (SR) and 284 Blended (BLD) goat breed types. Linear propensities of mortality in goat breeds were examined. Summarized data were analyzed using descriptive statistics to display distribution of diseases based on breed, sex, age group and seasonal pattern. Mortality trends indicated highest burden of death losses among BLD followed by PW in 2009. Pneumonia (46.4%), starvation (14.0%) and *Corynebacterium pseudotuberculosis* abscess (11.7%) were the first, second and third top overwhelming reasons of mortality. Mortality pattern among breeds revealed highest mortality in BLD (55.4%), intermediate in PW (29.8%) and low in SR (14.8%). In both BLD and PW, low mortality was observed in males than females. Also, mortality in adults (39.2%) was higher than kids (37.8%) and young (23.0%). Moreover, mortality was highest in cooler dry (49.5%) followed by long rainy (18.0%) short rainy (17.5%) and hot (15.0%). BLD was shown to be less resilient than SR and PW; and cooler dry season was the uppermost risky period. The higher mortality observed in this study underscore the need for improved management and disease control practices.

**Keywords:** *Clinical Signs; Disease; Goat Breeds; Mortality; Pathology*

### Introduction

Tanzania is endowed with abundant livestock resources, widespread rangelands and diverse natural vegetation suitable for browsing and grazing animals. Recent estimates indicate that there are about 32.2 million head of cattle, 5.5 million sheep, 20 million goats, 2.4 million pigs, 38.5 million local chickens, 40.6 million improved chickens and more than 60% of the total land area suitable for livestock farming [1]. Small ruminants donate more than 22% to the national meat supplies with goats contributing more than sheep. Goat meat is estimated at about 14% of the total red meat supply from ruminants in the country [2]. Goat farming is practiced by more than 30% of the agricultural households in the rural communities [3]. It is amongst the main components of agricultural activities, which sustain many economic reasons, vast ecological terms and diverse socio-cultural roles in smallholder traditional systems, pastoral and agro-pastoral societies [4]. Goats are credibly less troublesome to manage; generally more prolific, resistant to many of the diseases, have quick maturity traits and can thrive themselves on scarce fodder and forage plant species and threatening climate where other animal species may perhaps die [5]. They are primarily kept for meat production, which ranks second to beef in quantity [6]. Goat meat is an important

animal protein source in the diets of the poor in the rural areas and sustains the well-being of many traditional farmers in the country [7]. Also, goats provide extra income, manure, raw materials (hides and skins) and intangible benefits such as insurance against tragedies, savings and investments in addition to other socio-economic purposes and traditional culture rituals [8]. Thus, goats mark a very useful multipurpose input especially to the livelihood resilience and survival of the rural poor [7].

At present, the profitability of goat production in Tanzania is limited with a number of challenges that seriously affect its economic returns. High prevalence of diseases and parasites, high mortality rates and critical feed shortages are amongst the foremost constraints to goat productivity in this sector [9,10]. These constraints are considered to be major contributors to negative genetic progress and diminished benefits of high production performance in goats resulting in low production coefficients. Present figures indicate low kidding percentage 30 - 50%, low offtake rate of 15 - 25% per annum, low growth rates of 5 - 7 g/day, high kid mortality rates of 20 - 40%, adult mortality rates 8 - 15%, average carcass weight about 12 - 15 kg and poor nutritional status resulting in infertility and tremendous reproductive wastage such as delayed estrus, abortions and long kidding intervals [11]. In addition, management procedures in the semi-arid tropical regions are not ideal resulting in high morbidity and mortality mainly amongst neonates and the young [12]. Knowledge of goat mortality due to various reasons basing on breed, sex, age group and seasonal occurrence under a specific production system is relevant in developing herd health management to reduce incidences of morbidity and mortality [13]. It was therefore worthy carrying out this descriptive study to inspect various reasons and pattern of mortality cases in meat goat breed types nurtured under farm situations in the northern zone of Tanzania. This paper ultimately identified a set of management options for the forthcoming mortality control and amelioration in goat productivity in the semi-arid tropical climate.

### Materials and Methods

#### Study site

The study was carried out at the Tanzania Livestock Research Institute, West Kilimanjaro Centre in Northern Tanzania. The Centre is situated at 3°S latitude and 39°E longitude, at an altitude of approximately 1270 meters above sea level. The farm falls in the area, which is characterized by erratic rainfall ranging between 450 - 700 mm. The long rainy season extends from Late-March to May; whereas short rainy season occurs from November to December. Cooler dry season begins throughout June to October and is characterized by prolonged coldest and dry weather with recurrent cloudiness, slight fog, tiny snowfall and strong winds blowing at speed up to 25 km/hr. The hot season lasts on average from January to Mid-March. The area experiences temperature ranging between 11.7°C - 27.8°C. The soils are predominantly dark brown in colour and silt loam with extremely deprived moisture holding capacity due to its insufficiency in organic matter. The dominant vegetation type is savanna with Acacia trees, natural grass and legume pasture forages.

#### Study data

Mortality data on the diagnosed diseases/conditions in 513 goats died between 2005 and 2017 was obtained from the available animal health records of the Centre. Data regarding the epidemiological features such as age, breed and sex, date of death, clinical signs, pathological findings and conclusive diagnosis were recorded. The data consisted of 153 Pare White (PW), 76 Sonjo Red (SR) and 284 Blended (BLD) goat breed types. All animals were conserved under semi-intensive breeding environment with identical feeding status and sheltered in permanent wooden houses each with raised floor and size for caring up to 75 heads. Goats were allowed to browse green pasture forages during the day for 8 hours and were provided with fresh drinking water. Concentrate and vitamin-mineral supplementation and herd health care practices such as deworming and vaccination against anthrax were occasionally carried out. Peste des petits ruminants (PPR) and contagious caprine pleuropneumonia (CCPP) vaccines were not given to the farm animals for the whole period. Farm flocks were secured against possible interaction with animals from the neighboring settlements and pastoral societies.

#### Determination of reason for death

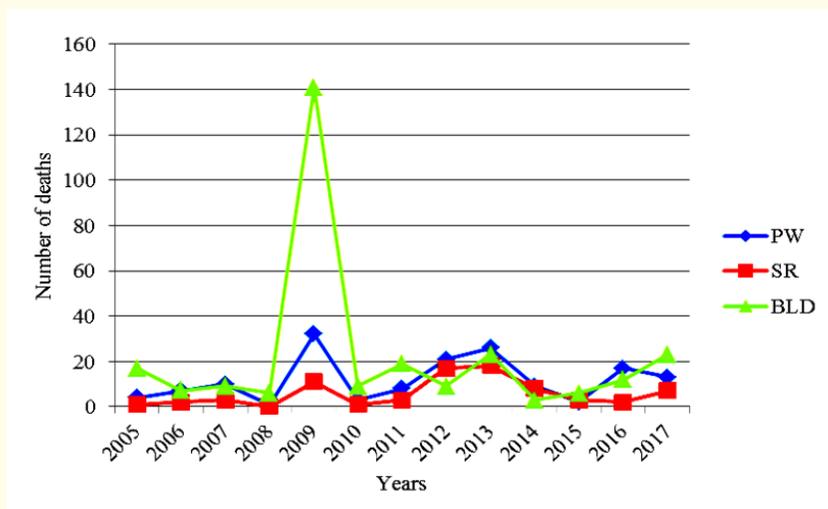
Reason for death was established based on observation of clinical signs, morphological characteristics of the parasites, lesions and pathological changes in organs and/or tissues following postmortem examination. Wherever manifold diseases or conditions were diagnosed, demise was accredited to the disease that produced the greatest pathology in critical organs and/or tissues.

**Data management and analysis**

Data obtained from the records were entered into Microsoft Excel spreadsheet and were summarized prior to analysis. The animals were grouped as kids (0 - 4 months), Young (4 - 12 months) and adults (More than 1 year). The seasonal classification was defined as follows: (a) January to Early March as hot season (b) Late March to May as long rainy season (c) June to October as cooler dry season and (d) November to December as short rainy season. Linear trends of mortality in goat breeds at the farm from 2005 to 2017 were examined. Summarized data were scrutinized and subjected to standard statistical procedures. Descriptive statistics were generated to display distribution of diseases/conditions based on breed, sex, age group and seasonal pattern, which were presented in tables. Number of deaths attributable to a specific cause/effect was calculated as the fraction of the total number of deaths due to all causes [14]. The rates of recurrence of diseases/conditions were presented in percentages.

**Results and Discussion**

Trends of mortality in goat breeds showed almost closely parallel inclinations and intersections, which might be depending on breed influences and variations in climate and management conditions between years (Figure 1). Along the trends, few deaths were usual in SR compared to PW. In 2009 there was very high burden of mortality; mostly in BLD followed by PW whereas in 2012 and 2014 the mortality in BLD was lower than PW and SR. The highest mortality in BLD and PW in 2009 might be due to the witnessed climate related disasters such as prolonged extreme weather and intensification of infectious diseases [15]. The extended drought condition might have caused poor rangeland conditions and critical feed shortage at the farm, which might result to imbalances between the diet consumed and metabolic needs of animals, and increased mortality due to starvation in that period. Also, nutritional stress from starvation might cause depressed resistance due to immune suppression, which might result to increased mortality from diseases, parasites or accidents that might perhaps be avoided [16]. BLD is a composite breed, which has combined mainly the blood of two large breeds (30% Boer of South Africa and 55% Kamorai of Pakistan) and 15% Tanzania indigenous goat [17]. The breed is much affected by feed shortage as its large size requires more nutrients compared to PW and SR. PW and SR are indigenous breed strains belonging to the Small East African (SEA) breed. Persistent low trend of mortality observed in SR indicates that the breed subtype is more resilient to the arid and semi-arid tropical conditions than PW and BLD.



**Figure 1:** Trends of mortality in goat breeds at the farm.

Reason for death	PW		SR		BLD		Total
	Male	Female	Male	Female	Male	Female	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Pneumonia	20 (3.90)	38 (7.41)	19 (3.70)	24 (4.68)	57 (11.1)	80 (15.6)	238 (46.4)
Starvation	14 (2.73)	8 (1.56)	5 (0.97)	4 (0.78)	15 (2.92)	26 (5.07)	72 (14.0)
Abscess	9 (1.76)	12 (2.34)	6 (1.17)	3 (0.60)	7 (1.36)	23 (4.48)	60 (11.7)
Traumatic injuries	4 (0.78)	3 (0.60)	4 (0.78)	0 (0.0)	5 (0.97)	17 (3.31)	33 (6.43)
Helminthosis (11 <i>H. contortus</i> , 5 <i>F. hepatica</i> , 2 <i>C. tenuicollis</i> )	3 (0.60)	3 (0.60)	1 (0.20)	1 (0.20)	8 (1.56)	2 (0.39)	18 (3.51)
Plant toxin	1 (0.20)	7 (1.36)	1 (0.20)	2 (0.39)	1 (0.20)	4 (0.78)	16 (3.12)
Rumen impaction (7 plastics, 5 mixed, 2 hair, 1 cloth)	1 (0.20)	6 (1.17)	1 (0.20)	1 (0.20)	0 (0.0)	6 (1.17)	15 (2.92)
Bloat (11 Frothy bloat, 3 Abomasal bloat)	2 (0.39)	4 (0.78)	0 (0.0)	1 (0.20)	3 (0.60)	4 (0.78)	14 (2.73)
Snake bite	3 (0.60)	2 (0.39)	1 (0.20)	0 (0.0)	1 (0.20)	5 (0.97)	12 (2.34)
Pox	2 (0.39)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.39)	6 (1.17)	10 (1.95)
Enteritis	1 (0.20)	4 (0.78)	1 (0.20)	0 (0.0)	3 (0.60)	1 (0.20)	10 (1.95)
Gastric trichobezoar	0 (0.0)	2 (0.39)	0 (0.0)	1 (0.20)	1 (0.20)	0 (0.0)	4 (0.78)
Tick infestation	0 (0.0)	1 (0.20)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.39)	3 (0.60)
Hepatic fatty cirrhosis	0 (0.0)	1 (0.20)	0 (0.0)	0 (0.0)	1 (0.20)	1 (0.20)	3 (0.60)
Obstructive atelectasis	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.20)	1 (0.20)	2 (0.39)
Dystocia	0 (0.0)	1 (0.20)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.20)
Salmonellosis	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.20)	0 (0.0)	1 (0.20)
Coccidiosis	1 (0.20)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.20)
Total for sex	61 (11.9)	92 (17.9)	39 (7.60)	37 (7.21)	106 (20.7)	178 (34.7)	
Total for breed	153 (29.8)		76 (14.8)		284 (55.4)		513 (100.0)

**Table 1:** Reasons of mortality in goats based on breed and sex-wise pattern.

Proportionate reasons of goat mortality centered on breed and sex pattern is presented in table 1. The most frequent diagnosed overwhelming reason of mortality was pneumonia, with 46.4% of the total cases, followed by starvation (14.0%), abscess (11.7%), traumatic injuries (6.43%), helminthiasis (3.51%), plant toxin (3.12%), rumen impaction (2.92%), bloat (2.73%), snake bite (2.34%), pox (1.95%), enteritis (1.95%) and gastric trichobezoar (0.78%). Other causes of mortality included Liver cirrhosis (0.60%), tick infestation (0.60%) and obstructive atelectasis (0.39%). Also, there were three other diseases or conditions with a single (0.20%) case of each, including dystocia, salmonellosis and coccidiosis. Mortality pattern among breeds revealed highest mortality in BLD (55.4%), intermediate in PW

(29.8%) and least in SR (14.8%). Fatality cases of pneumonia, starvation, abscess, traumatic injuries, helminthosis, bloat, snake bite and pox were uppermost in BLD followed by PW and SR; whereas, plant toxin, rumen impaction and enteritis caused most deaths in PW followed by BLD and SR. In both BLD and PW, low mortality was observed in males compared to females. In SR, mortality was somewhat higher in males (7.60%) than females (7.21%), but it is not certain if the difference is significant since the figures were not subjected to statistical test.

The higher mortality due to pneumonia observed in this study might be related to poor herd health management conditions such as reduced access to better nutrition, little effort to sanitary practices and deprived air quality circumstances in herd housing, which might result to severe stress, depressed immune function and increased impact of respiratory diseases to which goats are very vulnerable [18]. As well, several infectious diseases in goats such as PPR, CCPP, caprine arthritis and encephalitis can be characterized by pneumonia symptoms. Selenium and Vitamin C deficiency has been associated with the incidence of lung infections in small ruminants [19]. Goats that died of pneumonia showed signs of anorexia, dullness, acute depression, apathy, labored breathing, coughing, raised body temperature, mucus to mucopurulent nasal discharge, emaciation, sunken eyes and foamy nasal discharge. Pathological vicissitudes diagnosed were abnormal fluid in the pleural cavity, congested trachea and lungs, fibrinous observances in the thoracic cavity and external surface of the lung, hyperplasia of the bronchial tubes and mediastinal lymph nodes, hemorrhages over serosal exteriors, purulent otitis exudates in the bronchi, bronchioles and alveoli and frothy secretions in the respiratory tract. However, there were no clinical records of sorts of pneumonia and explicit etiological agents. Clinical diagnosis of pneumonia is intricate and it comprises physical examination for signs, imaging, serological testing, isolation and identification of etiological agents complemented with postmortem examination of the lungs. Pneumonia is often ranked as one of the most intense health problems of small ruminants in the tropics, which cause huge production losses through morbidity and mortality [20]. It can lead to momentous economic demolition due to demises, diminished live weight, marketing snags, high costs of prevention, control and treatment, and weakened thriftiness [21,22]. In one previous study on incidence and causes of mortality of goats in Nigeria [23], pneumonia accounted for 35.6% of all cases. Besides, Mellado, *et al.* [24] and Ramirez-Briebesca, *et al.* [25] reported pneumonia to be responsible for the death in 55% and 18% of goats necropsied, respectively, in Mexico. Moreover, Debien, *et al.* [26] reported pneumonia as the cause of mortality in 13.8% of goats submitted for necropsy in Quebec, Canada. In addition, it accounted for 38.24% of all fatality cases in goats in India [27]. Still, one study in Bangladesh suggested bacterial pneumonia as endemic that gives emphasis to the need for prevention and control measures [22].

Starvation was the second overwhelming reason of mortality in this study and it could be related to climatic conditions and minimal or lack of control and management of the grazing land according to seasonal variation, which might resulted to critical feed shortages due to poor range conditions. The risk of mortality due to starvation in goats might be triggered by minimal or absence of supplemental nutrition. The clinical signs observed in malnourished goats were wasting/emaciation related to loss of muscle mass, recumbent to conserve metabolic resources, hypothermia and failure to regain the standing position. Undernourished newborn kids were lethargic, failed to suckle colostrum for the first 36 hours after birth, gained heat shivering due to diminution of their limited body stores of energy generating nutrients and died. Postmortem findings showed complete exhaustion of body fat reserves, acute hyperemia of the intestinal mucosae indicative of demand for nutrients and carcasses showed muscle proteolysis. Starvation caused by poor forage condition has been reported to be among the main reasons of goat mortality in the arid and semi-arid tropical regions [28].

*Corynebacterium pseudotuberculosis* abscess was the third most frequent reason of goat mortality in this study and it was due to a chronic granulomatous infectious disease of farmed small ruminants called caseous lymphadenitis (CLA). The deaths from CLA in this study might be associated with absence of operational implementation of prevention strategies and effective control measures for the disease at the farm. The characteristic sign observed for the disease was swollen lymph nodes in front of the shoulder, in the flank, perineum and at the base of the ear. The locations of abscesses judged as the cause of death were perineal lymph nodes and visceral structures such as mesenteric lymph nodes, lungs (death due to respiratory failure) and liver (death due to liver failure). Thirteen goats that died from visceral abscesses were emaciated indicating systemic complications. Mortality data on pseudotuberculosis in this study showed that the

disease might be widespread within goat flocks and it deserves much attention due to its contagious nature and its importance in the contamination of meat and milk. However, there are scanty previous data in the Tanzanian literature on its prevalence on farms and its relative role in goat mortality. Clinical diagnosis of CLA is often difficult as most of the sick animals do not show clinical signs. The majority of cases are identified during postmortem examination. Also, its actual incidence has been understated since it is not a notifiable disease in many countries [29]. CLA has been reported as one of the most important causes of mortality in small ruminants and is responsible for significant economic damages for producers in some countries owing to reduction in the amount and quality of milk, culling of infected animals, downgrading of the infected organs and condemnation or trimming of carcasses at slaughter [29,30]. It accounted for 3.9% of the mortality in goats in Quebec, Canada and carcasses had internal infections [26].

Traumatic injuries and helminthosis were other important reasons for death losses in this study. Traumatic injuries might occur due to fighting, intense strike with blunt substances, trampling and sticking of legs at timber flooring spaces in raised houses. Injuries appraised as the cause of deaths were fractures, wounds and ventral abdominal hernia (torn parietal peritoneum and subcutaneous prolapse) caused by horn goring. The risk of injury in goats might be triggered by the neglect in husbandry practices such as dehorning and hoof trimming, and poorly maintained houses. Besides, fatality cases of helminthosis might be related to the adopted semi intensive husbandry practices of goat raising, their feeding habit (browsers), occasional deworming routine attached and direct transmission due to confinement. The presence of helminth parasites at the farm might perhaps linked to low lying location of the farm rangelands and polluted source of drinking water for the livestock. The clinical signs observed in some of the helminth infected goats were lack of appetite, hair depilation and weight loss, anemia with pallor of mucous membranes of the eyes and mouth, distended abdomen, weakness and finally death. Usually, helminth infestations in goats range from acute illness with frequent rates of high mortalities to various intensities of chronic disease with wavering degrees of morbidity. This is because goats have inferior ability to elicit a strong immune response against gastrointestinal parasites [31]. At autopsy, the helminth parasites incriminated as dominant cause of deaths were *Haemonchus contortus* with 11 (2.15%) cases followed by *Fasciola hepatica* 5 (0.97%) and *Cysticercus tenuicollis* 2 (0.39%). *H. contortus*, which is a blood sucking parasite, was seen attached in the abomasal mucosa. *F. hepatica* was found as immature flukes in the bile duct and gall bladder in the liver and it produced numerous lesions, which might cause serious damage to the infected organs. The prevalent abdominal locations for *C. tenuicollis* were omentum, mesentery and abomasum; few were embedded in the liver. Haemonchosis is a serious disease, detrimental to livestock health and productivity due to high morbidity, rapid mortalities and increased costs of management and prevention methods. The disease is often undiagnosed due to the nonspecific signs and absence of diarrhea and death can occur suddenly [32]. It was shown to be the second most significant cause of mortalities in small ruminants in Malaysia [33]. Further researchers reported haemonchosis in 16.47% of deaths in goats necropsied in Pakistan [34]. In another study in Brazil haemonchosis was observed to be endemic on the herds and it accounted for 14.5% of deaths in goats necropsied [35]. Besides, *F. hepatica* infestation leads to significant economic losses through high morbidity and mortality rates in domestic ruminants in endemic geographic areas. The disease can be easily mistaken for other conditions and in many serious cases sudden deaths happen without any clinical signs. Its prevalence is increasing in many areas of the world in association with warm, moist climatic conditions [36]. Still, scant research has focused on the epidemiology and economic loss of fasciolosis in the tropical region. The disease is classified as one of the most neglected tropical zoonotic diseases to stimulate research, education, awareness creation and sensitization amongst farmers on the infection and management [37]. A death case of one goat due to acute fasciolosis was reported by Hashemnia, *et al.* [38]. The observed mortality due to *C. tenuicollis* might be because heavy infestation caused secondary bacterial infection and/or severe liver damage resulting in sudden death [39].

Plant toxin accounted for 3.12% of all fatality cases in this study. The deaths from plant toxins might be caused when goats were starving due to poor forage condition of the grazing land brought by drought, over-grazing and invasive noxious plant species, which reduced the availability of quality sward species and forced the animals to browse extreme quantities of poisonous plants. In some plant species such as *Cynodon dactylon* etc. the stage of plant growth might be the reason for intoxications and consequential mortality although the most common reason for the toxic poisoning in goats is starvation [40]. Nine (1.75%) affected goats showed depression, tachycardia, noticeable jugular engorgement and purses, muscular trembles, quick collapses, sternal decubitus evolving to lateral recumbence, pad-

dling and died suddenly after the onset of acute clinical signs. Seven (1.37%) goats showed salivation, mydriasis, bradycardia, depression, staggering, ataxia, coma and death. Autopsy findings showed small multifocal hemorrhagic tumefaction in lungs, kidneys, heart and congestion of the intestines. The findings might be linked to acute plant poisoning, which might have arrested aerobic metabolism mostly in cells with a high metabolic rate such as neurons and cardiac myocytes leading to rapid death from anoxia. Noxious plants of animal interest have been causing momentous losses on the conservation of biodiversity in various parts of the world, heavily in the production of herbivorous animals on rangelands with the direct losses connected to mortality [41]. Lopes, *et al.* [42] reported neonatal deaths in kids fed with colostrum from doe goats ingested toxic plant in Brazil. The toxicogenic plants frequently flourishing at West Kilimanjaro farmland that can affect the well-being of domestic ruminants include *Datura stramonium* and *Solanum incanum* belonging to the family Solanaceae, *Rhaponticum repens* in the family Asteraceae and *Cynodon dactylon* in the family Poaceae. *C. dactylon* may become poisonous to the livestock due to tryptophan-derived mycotoxins called ergot alkaloids induced by the toxic fungus strains of *Claviceps spp.* growing in the grass [43].

Rumen impaction accounted for 2.92% of the mortalities. The deaths accredited to rumen impaction occurred due to agglomeration of a large quantity of indigestible foreign materials in the rumen, which resulted to impaction along with mucus and food material into the rumen. The ingestion of indigestible wastes in goats might be due to indiscriminate feeding habit triggered by mineral deficiencies, negative energy balance owing to poor nutritional supplementation and the semi intensive management attached to them as the animals were allowed to browse and graze during the day for 8 hours. The observed clinical findings were depression, anorexia, recurrent bloat, suspended rumination and progressive weight loss. The foreign bodies found in necropsied animals were plastic 7 (1.36%), mixed 5 (0.97%), hair 2 (0.39%) and cloth 1 (0.20%). The occurrence of plastics and cloths in the rumen of goats might be attributed to inappropriate disposal of foreign bodies in the area. A series of studies in different areas of the world have reported on rumen impaction in domestic ruminants due to ingestion of plastics and cloths [44-46], nonetheless, there are no refereed publications reporting mortality in goats due to rumen impaction.

Referring bloat, it accounted for 2.73% of the demises. The types judged as the reasons of deaths in goats necropsied in this study were frothy bloat with 11 (2.14%) cases and abomasal bloat 3 (0.59%). The deaths from frothy bloat were observed in adult and young goats with mature rumen whereas losses attributed to abomasal bloat were seen in kids less than four weeks of age. Frothy bloat might occur due to overconsumption of wet grasses and lush young pasture forages. The symptoms diagnosed in frothy bloated goats were progressive distension of the abdomen on the left side, restlessness, increased salivation, biting and kicking at the abdominal region, frequent defecation and urination, grunting and extension of the neck and head, respiratory distress, collapse and finally death occurred within a short time after the onset of clinical signs. Necropsy findings revealed distension of the rumen and excessive foaming of the ruminal contents, congestion of the upper respiratory tract, hemorrhage of the tracheal mucosa, the lungs were compressed and bloody fluid was seen in the pericardial sac. As well, abomasal bloat might occur due to low levels of immunity from insufficient colostrum intake, vitamin or mineral deficits, ingestion of foreign bodies and microbial or fungal infection of abomasal wall [47]. The clinical signs observed in this case were weariness, swollen bellies with tinkling and splashing sound, fluid inflation of the stomach, teeth grinding, diarrhea and death. At necropsy, a gas-fill and hemorrhagic inflammation of the abomasum were seen, the abomasal contents turned into dark colored, ulceration and perforation of the abomasal mucosa was observed. Bloat is the most rapid life-threatening disorder, which causes serious economic losses in the livestock industry. A series of scientists have clarified on the events of bloat in domestic ruminants [47-49], but there are no refereed articles summarizing bloat as a reason of mortality in goats.

Regarding snake bite, it was liable for 2.34% of the death losses. The accidents were considered to occur during the day time when the animals were grazing and browsing pastures. Among the demises, 7 goats died suddenly in the field with nonspecific clinical signs; only presented respiratory signs of distress and restlessness, and 5 goats were found died in their houses during morning routines. Physical examination revealed two distinctive puncture wounds on the muzzle in 5 goats, on the lower jaw and neck region in 3 goats, on the upper part of the leg below elbow in 3 goats and on the fetlock in 1 goat. The fang hemorrhages were localized in 7 goats indicating elapid

bite and copious in 5 goats indicating viper bite. In reality, the venom of elapid snakes is primarily neurotoxic, which attack the central nervous system and causes paralysis, cardiovascular collapse and death from respiratory failure within 20 minutes to 6 hours. But, the venom of viper snakes is mainly hemotoxic and it causes local pain, swelling, oedema and profuse bleeding from the fang site. It is taken up more slowly through the lymphatics causing severe local effects and acute renal failure in case of complications and usually death happens within 2 to 4 days [50]. Cobra (*Naja spp.*) and Puff adder (*Bitis arietans*) are most common venomous elapid and viper snakes present at the farm, respectively. Necropsy findings showed expansion of subcutaneous tissues and connective tissues of muscles at the site of fang marks due to oedema and haemorrhage. In most carcasses, the lungs were congested and edematous, marked haemorrhages were observed on the lung and liver parenchyma, and the lumen of trachea was filled with frothy discharges. Also, multifocal petechial haemorrhages were diagnosed on the peritoneum and epicardium of heart. Snake-bite envenoming exhibits diverse diagnostic signs and it can be misdiagnosed with acute plant or other poisoning cases when the history of snakebite is absent especially in areas where the ailment is not common. However, in this study, sudden death with nonspecific clinical signs and presence of two fang puncture marks were clear indications of venomous snake bite [50,51]. The demises caused by snake-bite envenoming in this study makes it the significant disease diagnosed as it suggests broad impact to the public in terms of the burden of ailment and the poverty it causes as regards to mortality in domestic animals and potential economic losses. Venomous snake bites are liable for more than one hundred thousand deaths of animals in the World annually. Yet, the health systems in many countries where snake bites are common often lack the appropriate arrangements to collect strong statistical data on the problem [52]. This challenge makes a large proportion of the actual burden in the livestock to be unreported resulting to small number of observations and studies [53]. As a concern, snake-bite envenoming is contained within the list of priority neglected tropical diseases to stimulate numerous studies on the problem including its ecological determinants and supplement impetus to anti-venom development and funding investments for snake-bite prevention and treatment access ingenuities [52]. Several studies in the region have described the pathology of snake-bite in domestic ruminants [51,54,55].

Pox was another infection, which caused momentous demises. The mortality due to pox was attributed to severe systemic infection by virus of the genus *Capripoxvirus* classified in the subfamily *Chordopoxvirinae* of the family *Poxviridae*. This outbreak could be due to poor consideration of biosecurity measures and absence of regular prophylactic immunization of goat flocks. Diseased goats had high fever, depression, dyspnoea, peri-ocular swelling, nasal and ocular discharge, and excessive salivation. Six goats had acute respiratory distress and apparent pox lesions on the buccal and nasal mucosa, 1 goat was recumbent with foot lesions and 4 goats died without observable pox lesions. External autopsy results revealed raised epidermal lesions, erosive mucosal lesions on the nostrils and mouth, and evidence of the discharge described above. Further post-mortem findings showed ulcerations in the lining of the trachea and gastro-intestinal tract and lesions consisting of pale grey nodules in the lung. The clinical signs and diagnosed pathological changes in organs were indicative of malignant form of pox. This form of the disease is most serious and may cause high morbidity and mortality resulting to losses of production, damage to hide and skin and trade restrictions, and hence severe economic threat mainly to poor resource farmers. It has been reported to be more severe in kids and young animals than adults [56]. In susceptible herds, morbidity is often cited as 70 - 90% whereas the mortality in endemic regions reaches 5 - 10% in the outbreaks depending on the virulence of the pox virus. Indigenous breeds of goats are considered far less susceptible than exotic breeds introduced from Europe and Australia, in which infection and mortality are often approaching 100% [56,57].

Enteritis was a further fatal infection diagnosed in this study. This outbreak could be linked to indigestion produced by a sudden change in the diet due to alterations in grazing and climatic conditions, which might have triggered explosive growth and persistence of microorganisms responsible for the deaths in this case [23,58]. The risk of the disease eruption might be increased with inadequate hygiene. In 4 goats, the disease was characterized by a very rapid onset of symptoms such as acute distress, repeated laying on the sides, panting, grunting, recumbent with paddling and extension of the legs with the head and neck extended back over the withers. This last posture might be due to the effects of the toxins produced by microorganisms on the brain and deaths occurred shortly after this sign was observed. Three goats were found dead with no previous signs of the disease and 3 goats had diarrhoea with blood visible in the loose stool. The clinical signs were suggestive of *Clostridium perfringens* type D infection in goats. At post mortem, the most prominent

pathological changes were diagnosed at the small intestine, which was distended with gas and profuse infiltration of the haemorrhagic fluid and had a reddened and congested external appearance. In 5 goats, the lungs consisted of abundant froth in the trachea and bronchi and severe pleural, intra-alveolar and interstitial oedema. Enteritis is viewed as a frequently infectious fatal devastating disease of small ruminants. It has a worldwide distribution and affects animals of all ages [59]. It is among the endemic diseases in Pakistan and it causes mortality up to 100% in young kids [60]. As well, it accounted for 20%, 12.5%, 38.24%, 17.1% and 12% of all deaths in goats in Mexico, Nigeria, India, Canada and Brazil, respectively [23,24,26,27,35].

Gastric trichobezoar was diagnosed as another overwhelming reason of demises as well. It might be due to pathological ingestion of the animals' own hairs (trichophagy), which caused agglomeration of hairs in a concretion form in the rumen, reticulum and abomasum and further in the intestinal tract resulting to obstruction and obstacle in the pyloric outlet. Trichophagy is characterized by obstinate suckling of congeners or excessive licking as a result of confinement in a synthetic environment, skin irritation and deficiency in vitamins, proteins, fibers, trace minerals or both [61]. Clinically, bezoar goats were presented with slightly distended abdomen, weakness, anorexia, progressive dysphagia, vomiting, scanty fecal matter, considerable weight loss and compromised nutritional status. Grossly at autopsy, the four carcasses were emaciated. In two carcasses, ingested hairs were found in the abomasum, which might cause obstruction in the pyloric orifice (obstruction within the abomasum outlet into the intestinal tract); whereas, in the other two, hair balls were found in the rumen due to gastric motility and might cause blockage of the reticulo-omasal orifice. These problems were advocated to have caused aggregation of the stomach contents, which inhibited the passage of ingestion in the gastrointestinal tract. Bezoar is considered as an unusual occurrence in goats with merely rare cases being reported [62]. Its incidence is minor in goats than sheep as the former are more skillful in their feeding habit [63]. Fatal cases of tichobezoar in goats have been reported in Scotland [64], Nigeria [62] and India [63].

Regarding mortality pattern among breeds, the higher deaths in BLD could be attributed to their low adaptation to the East African tropical climate compared to PW and SR. This is because BLD is a three-way synthetic breed, which has 85% blood of two exotic breeds; whereas, PW and SR belong to the SEA breed. In parts of the year when there are climate related catastrophes such as extended drought condition and high parasite and disease cycles, BLD is not genetically fortified to deal with these problems in ways that can tolerate and minimize the death losses. The low mortality in males in both BLD and PW could perhaps due to the reason that the males especially in early ages are known to be vigorous and hence obtain more nutrients than females. Also, it could be because the males are intensively culled to keep least possible number of males for breeding purpose for limited periods of time [65].

Proportionate reasons of goat mortality in different age groups are summarized in table 2. The mortality in adults (41.1%) was higher than kids (35.9%) and young (23.0%). The mortality cases of pneumonia, starvation, pox and enteritis were higher in kids compared young and adults; whereas, helminthosis caused somewhat greater losses in young (1.75%) than adults (1.36%), and low mortality in kids (0.39%). Moreover, the circumstances of abscess, traumatic injuries, plant toxin, rumen impaction and snake bite were higher in adults than other age groups. The higher death cases of pneumonia observed in kids in this study could be due to poor immunity related to deficiency of colostrum, stress and insufficient feeding rising from little postnatal care given. In one previous study in Bangladesh [66], pneumonia was the prime reason for kid mortality (42.2%) similar to the results of Chowdhury, *et al.* [67], but higher than the value observed in this study. In young and adults, this outbreak could be due to stress related to poor feeding, which might have caused lowered immune barriers and antibacterial mechanism of the lungs leading to infection [18,68]. Kid mortality from starvation might be related to deficient nutrition of does during pregnancy mainly during the last trimester when most fetal growth occurs. In doe goats, this could result to poor maternal performance, production of less and lower quality colostrum loss of milk production and body condition, and restricted bonding with neonates [69]. Most of the new born kids could have lighter weight, suffered serious depletion of body reserves due to lack of colostrum and died in the in first few hours from starvation-hypothermia syndrome; whereas, others could have died in short periods due to inborn weakness. Van der Westhuizen [70] reported birth of weak kids with high mortality from does that were underfed during pregnancy. The results of age-wise mortality due to pox disclose that the outbreak is usually more severe in kids and young goats, with most demises occurring in these groups. Moreover, the results of enteritis conform to Nzekwu [71] who reported more deaths in kids and young goats during their early stages of life.

Reason for death	Kid	Young	Adult
	n (%)	n (%)	n (%)
Pneumonia	90 (17.5)	63 (12.3)	85 (16.6)
Starvation	62 (12.1)	5 (0.97)	5 (0.97)
Abscess	4 (0.78)	13 (2.53)	43 (8.38)
Traumatic injuries	1 (0.20)	7 (1.36)	25 (4.87)
Helminthosis (11 <i>H. contortus</i> , 5 <i>F. hepatica</i> , 2 <i>C. tenuicollis</i> )	2 (0.39)	9 (1.75)	7 (1.36)
Plant toxin	1 (0.20)	3 (0.60)	12 (2.34)
Rumen impaction (7 plastics, 5 mixed, 2 hair, 1 cloth)	1 (0.20)	2 (0.39)	12 (2.34)
Bloat (11 Frothy bloat, 3 Abomasal bloat)	4 (0.78)	5 (0.97)	5 (0.97)
Snake bite	0 (0.0)	3 (0.60)	9 (1.75)
Pox	8 (1.56)	2 (0.39)	0 (0.0)
Enteritis	5 (0.97)	3 (0.60)	2 (0.39)
Gastric trichobezoar	2 (0.39)	2 (0.39)	0 (0.0)
Tick infestation	1 (0.20)	0 (0.0)	2 (0.39)
Hepatic fatty cirrhosis	0 (0.0)	0 (0.0)	3 (0.60)
Obstructive atelectasis	2 (0.39)	0 (0.0)	0 (0.0)
Dystocia	0 (0.0)	0 (0.0)	1 (0.20)
Salmonellosis	1 (0.20)	0 (0.0)	0 (0.0)
Coccidiosis	0 (0.0)	1 (0.20)	0 (0.0)
<b>Total</b>	<b>184 (35.9)</b>	<b>118 (23.0)</b>	<b>211 (41.1)</b>

Table 2: Reasons of mortality in goats based on age-wise pattern.

Proportionate reasons of goat mortality in different seasons are summarized in table 3. The mortality was highest during cooler dry season (49.5%) followed by long rainy season (18.0%), short rainy season (17.5%) and hot season (15.0%) of the years. Also, most of the deaths due to pneumonia, starvation, abscess, traumatic injuries, plant toxin, rumen impaction, snake bite, pox and trichobezoar were observed in winter season; whereas, helminthosis, bloat and enteritis were more prominent in long rainy season. The highest number of death cases in cooler dry season could be explained and associated to the fact that during this period of the year, which covers five months, usually, there is coldest weather with strong winds and extended drought situation, hence animals suffer cold stress and lack of green pasture facilities and come down with depressed immune functions and diseases. This effect of declining conditions in cooler dry season might perhaps be continued into early short rainy season. Also, the fact explained above might be the reason for high incidences of pneumonia, starvation, plant toxin, rumen impaction, pox and trichobezoar in cooler dry compared to other seasons. In this study, more loss from helminthosis in the rainy season could be due to high numbers of helminth eggs in the pasture. Usually, the rise of humidity in the rainy and warm weather activates the hatching, survival and propagation of intestinal helminths and the risk of disease transmission may perhaps be extended into winter season [72] as witnessed in the current study. Also, the higher cases of bloat diagnosed in rainy season are related to consumption of young leaves, lush grasses and weeds. Equally, many cases of enteritis diagnosed in this season are absolutely due to pathogenic infection. Many deaths in goats in these seasons are credible due to variation of incidence of diseases and availability of pasture facilities between seasons [13].

Reason for death	Hot season	Long rainy season	Cooler dry season	Short rainy season
	n (%)	n (%)	n (%)	n (%)
Pneumonia	32 (6.24)	24 (4.68)	133 (25.9)	49 (9.55)
Starvation	5 (0.97)	24 (4.68)	37 (7.21)	6 (1.17)
Abscess	14 (2.73)	5 (0.97)	29 (5.65)	12 (2.34)
Traumatic injuries	9 (1.75)	4 (0.78)	12 (2.34)	8 (1.56)
Helminthosis (11 <i>H. contortus</i> , 5 <i>F. hepatica</i> , 2 <i>C. tenuicollis</i> )	5 (0.97)	7 (1.36)	5 (0.97)	1 (0.20)
Plant toxin	4 (0.78)	4 (0.78)	6 (1.17)	2 (0.39)
Rumen impaction (7 plastics, 5 mixed, 2 hair, 1 cloth)	3 (0.60)	1 (0.20)	9 (1.75)	2 (0.39)
Bloat (11 Frothy bloat, 3 Abomasal bloat)	0 (0.0)	11 (2.14)	2 (0.39)	1 (0.20)
Snake bite	3 (0.60)	0 (0.0)	7 (1.36)	2 (0.39)
Pox	1 (0.20)	4 (0.78)	5 (0.97)	0 (0.0)
Enteritis	0 (0.0)	6 (1.17)	0 (0.0)	4 (0.78)
Gastric trichobezoar	0 (0.0)	0 (0.0)	3 (0.60)	1 (0.20)
Tick infestation	0 (0.0)	0 (0.0)	2 (0.39)	1 (0.20)
Hepatic fatty cirrhosis	1 (0.20)	1 (0.20)	0 (0.0)	1 (0.20)
Obstructive atelectasis	0 (0.0)	0 (0.0)	2 (0.39)	0 (0.0)
Dystocia	0 (0.0)	1 (0.20)	0 (0.0)	0 (0.0)
Salmonellosis	0 (0.0)	0 (0.0)	1 (0.20)	0 (0.0)
Coccidiosis	0 (0.0)	0 (0.0)	1 (0.20)	0 (0.0)
Total	77 (15.0)	92 (18.0)	254 (49.5)	90 (17.5)

Table 3: Reasons of mortality in goats based on season-wise pattern.

### Conclusion and Recommendations

The reasons of mortality in goats in this study were in decreasing order. Pneumonia, starvation and abscess were the main overwhelming reasons of mortality among the breed types, age groups and seasons. BLD was shown to be less resilient than SR and PW; and cooler dry season was the highest risky time of the year. Sub-optimal nutrition and herd health management were the main predisposing factors. The outbreak of pneumonia can be reduced by implementing optimal hygienic and air quality measures in herd housing, nullifying overcrowding and provision of healthy diet, *ad libitum* water and mineral supplements to enhance immune function. The potential fatalities can be minimized through comprehensive diagnostic methods, effective treatment and provision of improved health care. Besides, starvation can be minimized by improving the feeding quality of the rangeland through the irrigation practices mainly during cooler dry season, over-sowing the natural grassland with legume pasture and conservation by deferred or buffer grazing. Planned use of supplementary feeds from crop residues and agro-industrial by-products is another approach to improve the feeding of animals mainly during critical feed shortage. Further, the risk of spread of abscess due to *C. pseudotuberculosis* infection must be reduced through combination of serological detection and culling of infected animals. Husbandry practices such as dehorning, trimming of hooves and maintenance of the quarters, and rational disease control through periodic vaccination, vector control, treatment, biosecurity measures and prophylactic immunization of goat flocks are advised as well.

### Limitation of the Study

This data based study is an account of diagnoses of mortality in meat goat breed types reared at West Kilimanjaro Livestock Research Centre for conservation, performance evaluation and utilization. A concealed limitation of the study is that during the time when the data were recorded, capability of the tools and other considerations did not allow for further comprehensive, exhaustive indicative procedures such as diagnostic imaging, serological testing, microbial isolation, microscopic examination, toxicological testing, etc. Yet, postmortem remains a very valuable diagnostic tool with substantial potential in presenting reliable verification of the main reasons of death on the basis of advanced clinical signs.

### Declaration of Competing Interest

The authors declare that they have no competing or conflict of interest regarding the work presented in this article.

### Acknowledgement

The authors genuinely express cordial thanks to supporting staff of the West Kilimanjaro Livestock Research Centre for their vigorous contribution in herd management.

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**Volume 5 Issue 9 September 2020**

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