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Goat Science

From Keeping to Precision Production

Edited by Sándor Kukovics

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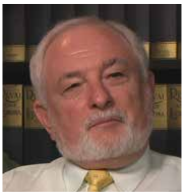
Meet the editor



Prof. Dr. Sándor Kukovics spent 40 years at the Research Institute for Animal Breeding and Nutrition, Hungary where he was responsible for the small ruminants sector. He has edited 39 books, published more than 1000 articles, and obtained licenses for 4 products. Besides research work, Dr. Kukovics has taken part in under- and further education at various universities in Hungary. He has been president of the Hungarian Sheep and Goat Dairying Public Utility Association since 1996 and the executive manager of the Sheep and Goat Products' Board (Hungary) since 2010. During 2015–2019, Dr. Kukovics served as vice president of the EU COPA-COGECA Working Party on Sheep and Goats. He has been a member of the board of directors of the International Goat Association since 2016.

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Preface

Goat farming contributes significantly to the world economy and is of particular importance in developing countries where it can be a means of reducing poverty. This book provides a comprehensive overview of goat husbandry.

Breeding and History

Chapter 1 discusses the domestication of goats and the development of goat breeds and their spread on different continents. It summarizes old and new methods of increasing the performance of goats, natural and artificial selection, and selection based on traditional and molecular genetics. The chapter also discusses the development of various production traits (milk, meat, wool, fertility, resilience, etc.), their continuous improvement, and the results achieved by using molecular genetics methods developed in the last 30 years.

Traditional selection requires a lot of time and costs, whereas new methods can save time and money by determining the genetic values of the animals right after their birth. The chapter presents some of these new methods along with the details of traditional and precision-based animal husbandry and product production.

In recent decades, there has been a focus on increasing production of milk, fertility, meat, and wool in the goat sector. The possibilities of increasing production in goats have already been exploited in the case of most indigenous local breeds. Therefore, the question arises of whether to breed new foreign breeds within the species or crossbreed with exotic breeds in order to increase yields. Each solution has its advantages and disadvantages. Chapter 2 discusses the possibilities and expected consequences of purebred breeding and crossings. There are still untapped opportunities in purebred breeding in individual regions and the use of crossbreeding could lead to greater progress.

Genetics

The opportunities provided by the application of molecular genetic methods are playing an increasingly important role in the preservation and breeding of individual goat breeds, as well as in the evaluation and possible improvement of their production properties (meat, milk, hair and wool, fertility, etc.). Chapter 3 discusses some of these methods and their results.

The results of DNA tests provide an extremely good opportunity to investigate the kinship of herds of different breeds bred in the same or neighbouring regions. Not only can the distance between the breeds be determined with these tools but the polymorphism and degree of kinship within each breed can also be determined. Chapter 4 summarizes DNA test results of goat breeds in Nigeria.

Reproduction and Biotechnology

Almost every region that keeps goats has its own breeds that have been developed and bred there. To increase the production of meat and milk, exotic breeds have been gaining more and more space in these regions as well, both in purebred breeding and crossbreeding. This process can lead to the dilution of the genetic stock of varieties created under local conditions and to the loss of some of their useful properties. Chapter 5 evaluates the improvement of reproduction abilities and the possibilities of using different breeding and biotechnological methods and tools in the Black Bengal Goat breed in Bangladesh, a species that plays a major role in the fight against local poverty.

Animal Health

Excellent breeding, genetic work, and precision farming are useless if there is a problem with the health of the animals. Chapter 6 discusses diseases in goats, including their symptoms, causes, treatment, and prevention.

Goats are susceptible to endo- and ectoparasites, and parasitic infections reduce milk, meat, and wool production. Internal parasites (protozoa and helminths) damage organs, especially the gastrointestinal tract, and reduce the absorption of digested food. External parasites (lice, fleas, flies, ticks, and mites) damage the skin, are responsible for blood loss, and spread many pathogens. Timely diagnosis of parasitic infections reduces damage and production losses. Chapter 7 presents detailed information on the types, effects, prevention, and treatment of parasites in goats.

With the development of diagnostics, parasitic infections can be recognized more easily and accurately. Many antiparasitic drugs are available to treat parasitic infections, but their irrational use can lead to the development of resistant parasites. Alternative techniques such as phytotherapy, biological control, grazing, bioactive plants, and nutrition reduce the risk of parasite resistance.

Goats can be attacked by many types of external and internal parasites, which reduce the animals' resistance to disease and production capacity. Assessing the parasite infestation of a goat herd in a given country is of fundamental importance in determining the necessary treatment for the animals. Chapter 8 presents a study conducted in Ireland on the protection methods used against parasites and the determination of the composition of the fauna of the various gastrointestinal parasite populations.

According to the results of the tests, the presence of individual types of parasites is high in both adult animals and kids, which indicates the use of inadequate protection and elimination methods and tools. As such, it is essential and urgent for goat keepers to receive more training.

Trypanosomiasis is one of the major diseases hindering livestock production in tropical Africa. It limits livestock breeding and animal product production, especially for small ruminants and other ruminant species. Chapter 9 investigates the presence of this disease in some regions of Nigeria. According to the results of the investigation, there is a low level of infection, which may mean that individuals of the herds sampled in the region may be resistant to trypanosomiasis. However, this does not mean the complete absence of the presence of infection. Therefore, the regular examination of stocks is still justified, and the need to introduce newer and more sensitive methods of testing is also well founded.

There are various medicinal preparations as well as medicinal plants used to protect animals against pathogens. Chapter 10 examines the antibacterial, antifungal, and antiparasitic effects of wood vinegar from *Eucalyptus grandis*.

Nutrition

A decisive question in goat feeding is always whether the goats can eat certain plants. The plant's digestibility, nutritional value, mineral content, fiber content, and so on must be considered to ensure the plant is not harmful to the animal. Chapter 11 discusses the potential role of cowpea as feed for goats in Nigeria.

Adaptation to Global Warming

In addition to the quantity and quality of available feed, the quality of drinking water and protection from heat are crucial for animals. This is especially important in desert and hot climate regions. Chapter 12 indicates that watering every other day and the presence of available shade profoundly influence the reproductive characteristics of desert goats and the survival of their kids.

Socio-Economics – Adaption Knowledge for Survival

In developing countries, goat farming plays a particularly important role. The goat is referred to as the poor man's cow because goats require a relatively small investment and goat husbandry can reduce the pressure of poverty. In developing countries, the backbone of the rural economy is agriculture and related activities, especially livestock. Agriculture is crucial for socioeconomic progress, income generation, and the general well-being of rural farmers. In the rural sector, animal husbandry is key to increasing household income and creating productive jobs. Chapter 13 summarizes the results of a survey carried out in the West Bengal region of India that assessed the conditions and economic possibilities of about 5,000 goat farms. India has the largest population of goats in the world, but the productivity of the animals is low and the training of the keepers is minimal. There are also large socioeconomic differences among livestock owners.

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Section 1

Breeding and History

Chapter 1

History of the Goat and Modern versus Old Strategies to Enhance the Genetic Performance

Ahmed A. Saleh, Amr M.A. Rashad, Nada N.A.M. Hassanine, Mahmoud A. Sharaby and Sobhy M.A. Sallam

Abstract

This chapter was designed to figure out the basic knowledge about domestication, adaptation and immigration of goat breeds, with a spotlight on modern versus old strategies to enhance genetic performance along with recognizing their role in the livestock production industry with a special focus on the position adaptive selection in view of the new high technologies of investigating genome and building of selective comparison between goat breeds. Also, this chapter focused on goat production throughout the world, the vital role played by goats and the biodiversity of goat genetic resources and the special characteristics of goats under different conditions. In addition, this chapter is concerned with modern strategies to enhance goat genetic performance, including different molecular tools, besides mentioning the outcomes of utilizing advanced molecular tools in goat breeding, as well as identification of candidate genes related to important economic traits, detection of signatures of selection and quantitative trait loci, applied genome-wide association studies and the methodology of genomic selection, where the recent findings of genomic studies on goats are listed in a logical and sequential fashion.

Keywords: history, immigration, domestication, *Capra Hircus*, molecular tools, QTL, NGS, signatures of selection, GWAS, SNP chip, genomic selection

1. Introduction

Goats play an important role in the livelihood of a large proportion of small and marginal holders [1–3]. Moreover, the genetic diversity of goat breeds is indispensable to meet current production needs under various environments, allows sustainable genetic improvement and facilitates rapid adaptation to changing breeding objectives. Characterization and determination of genetic differences between and within goat breeds are potential tools to help the rapid improvement of economically important traits [4–6].

Attempts were made to increase meat, milk and fibre (hair and cashmere) production of goats. Most of the attempts were made traditionally through changing production systems and reproductive management but recently, by introducing high prolificacy genes and detecting the changes in the whole genome which affect fertility, fibre and growth traits [7, 8].

There are many minor genes scattered across the genome that influence most goat traits of economic importance, as well as specific environmental factors. Traditionally, phenotypic information was used to improve quantitative traits, but now phenotypic and genotypic information is needed to improve quantitative traits. Traditionally, pedigree-assisted selection and progeny testing have been used widely to improve many of these production traits. However, these traits are mostly low or medium heritable which may slow down improvement rates. Recent researches proved that some of such traits could be controlled by major genes or candidate genes, signatures of selection (SS), molecular markers, selective sweeps and quantitative trait loci (QTL) which can be traced along with their influence by the application of some advanced molecular tools, such as next-generation sequencing (NGS) or whole-genome sequencing (WGS) or high-throughput single-nucleotide polymorphism (SNP) genotyping [9, 10].

In general, traditional animal breeding techniques for improving such traits of concern are usually costly and take a long time and some undesirable traits may appear in offspring throughout the process of improvement. The genomic selection (GS) based on second-generation sequencing (next-generation sequencing) and third-generation sequencing (single-molecule real-time, SMRT) are promising alternatives for improvement that enable the animal breeders to select eligible animals with desirable traits such as longevity, fertility, litter size and disease resistance at early ages. This will result in an increase in the accuracy of the selection response [11].

During the past few decades, advances in molecular genetics have led to the identification of multiple genes, genetic markers, signatures of selection, selective sweeps, candidate genes associated with traits of interest in livestock also, detection of QTLs, obtaining the mitochondrial DNA (mtDNA) and describing the whole-genome sequencing (WGS), thus, marker-assisted selection (MAS), genome-wide studies (GWS), genome-wide association studies (GWAS) and genomic selection (GS).

This has provided opportunities to enhance the response of selection, in particular for traits that are difficult to improve by conventional selection such as low heritable traits or those whose phenotype measurement on selection candidates is difficult, expensive, only possible late in life or not possible [12, 13].

The general aims of this chapter were to introduce fundamental knowledge about the history, immigration of goat and modern versus old strategies to enhance goat genetic performance. Also, investigating the vital role played by goat, genetic diversity in goat, molecular tools in goat breeding, major genes related to economic traits and adaptation, the methodology of genomic selection (GS) and recent genome studies on goat by extracting the most important findings in the reliable studies with focusing on the recent studies.

2. Methodology

2.1 The objectives

There were several objectives in the current chapter: 1) investigate the worldwide goat distribution, 2) assess the worldwide goat production between the past and the present, 3) take a deep spotlight on the history and immigration of goats, 4) follow the goat domestication from the domestication centre to the different continents in the world, 5) evaluate modern versus old strategies to enhance goat genetic performance, 6) searching deeply in the recent reliable studies and genetic databases about the major genes or candidate genes, signatures of selection (SS), molecular markers, selective sweeps and quantitative trait loci (QTL) which associated with most important economic traits in the goats, 7) proposing a methodology to apply the genomic selection in the view of recent and reliable genome-wide association studies, 8) investigating the outcomes of utilizing advanced molecular tools in goat breeding and 9) finally, preparing a remarkable chapter as a reference guide for preserving the effort and time required to search hundreds of investigations and studies related to goat science.

2.2 Investigation sources

More than 590 references (varied between published papers, scientific periodicals, international books, master's and doctoral dissertations) published *via* Springer, Elsevier, Intech Open, Wiley, Taylor & Francis publishers, etc. were thoroughly investigated to extract all possible knowledge about the goats.

Also, the global databases related to animal production sector (especially goats) and genome databases were also used, as follows:

1. FAO Database (https://www.fao.org).

2. Animal QTL Database: (https://www.animalgenome.org/cgi-bin/QTLdb/index).

3. Genome Informatics Resources: (https://www.animalgenome.org/bioinfo).

4. Goat genome browser: (https://www.ensembl.org/Capra_hircus/Info/Index).

5. International Goat Genome Consortium: (https://www.goatgenome.org).

6. Var. Goats project: (https://gsejournal.biomedcentral.com/articles/10.1186/s12711–021–00659-6).

7. AdaptMap project.

3. The Goat (*Capra Hircus*)

3.1 Worldwide goat production

Goat is one of the oldest domesticated animals. According to genetic data and archaeo-zoological references, goats have been domesticated 10,000 years ago, in the region from Eastern-Anatolia to the Mountains of Zagros north of Iran (**Figure 1**), while the archaeo-zoological evidence suggests that they were domesticated from 8000 to 9000 years ago in the near east [14, 15].

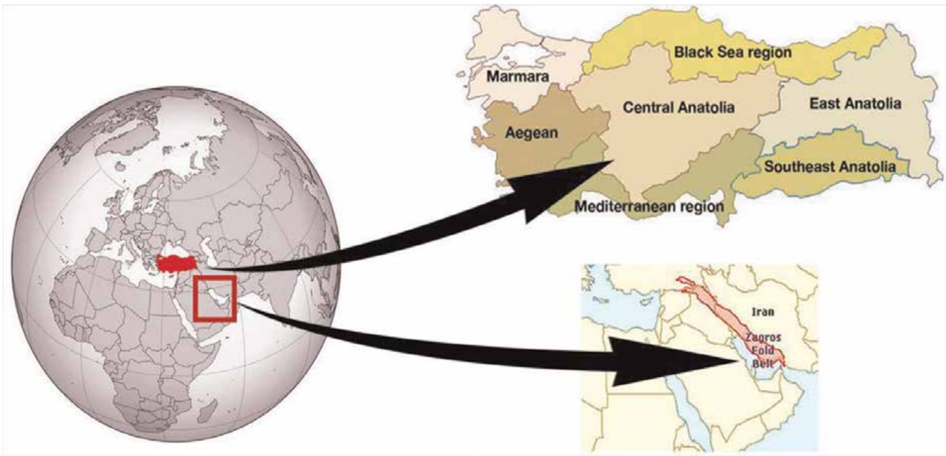

Figure 1.
Goat domestication in the region from eastern-Anatolia in Turkey to the mountains of Zagros in the north of Iran in the past 10,000 years (developed by the authors).

Goats are among the big five livestock species (chickens, goat, sheep, cattle and pigs) recognized by the FAO [16, 17]. FAO Database contains more than 800,000,000 specimens from more than 1200 goat breeds throughout the world. Globally, there are more than one billion goats. Goat is referred to as a poor man's cow [18]. Domesticated goats are generally utilized for producing meat, milk, fat, skin, hides, fibre or cashmere [18] worldwide [19, 20] **(Table 1)**, and are also used for transport [20].

Several factors have contributed to the differences among breeds. These differences are classified according to suitability to different purposes, breeding systems and adaptability to many environments [20]. Above 600 breeds of goat have been developed worldwide. These breeds differ from each other in their phenotypic characteristics and were adapted to different climatic conditions and extreme environments [20]. After domestication, goats were spread globally very quickly through commercial trades and human migrations [21, 22]. When comparing goats with other species, such as cattle, sheep and pigs, they have undergone an increase (+34%) in population since the year 2000 larger than cattle (+14%), sheep (+14%) and pigs (+15%) [20]. Goat production is one of the key elements contributing to the economy of farmers living in arid and semi-arid regions [23]. They play a necessary role in the livelihood of a large proportion of small and marginal holders. Moreover, goats are easy to manage and house, so that they can be raised by children, women and small families. Simply goats provide a reliable source of food for billions of people [10, 20].

Furthermore, the genetic diversity of goat is indispensable to meat, milk and hair current production needs under various environments, allowing sustained genetic improvement and facilitating rapid adaptation to changing breeding objectives [24]. Goats show reasonable production performance and reproductive behaviour. However, it is important to improve the productive and reproductive efficiency of goats to become more competitive, with other species [25, 26]. In many countries, goat breeds have been selected for special production traits, for example meat (Boer and Landrace), milk (Alpine and Saanen) and fibre (Cashmere and Angora) [20].

Region	No. of goats	Meat Pro. (Tones)	Meat pro. (Head)	Fat pro. (Tones)	Fat pro. (Head)	Skin pro. (Tones)	Skin pro. (Head)	Milk pro. (Tones)	Milk pro. (Head)
World	—	6,142,140	495,108,884	247,626	495,108,884	1,232,880	495,108,884	20,629,610	220,921,370
Africa	489,021,886	—	—	40,541	131,262,796	263,922	131,262,796	4,487,005	86,250,504
Eastern Africa	183,591,469	503,788	48,064,791	16,730	48,064,791	111,463	48,064,791	1,683,703	26,597,994
Middle Africa	62,667,249	215,838	17,317,883	5483	17,317,883	32,579	17,317,883	171,813	2,780,743
Northern Africa	47,874,919	205,372	19,824,364	5765	19,824,364	38,763	19,824,364	1,582,893	23,969,051
Southern Africa	9,452,259	21,558	1,512,674	485	1,512,674	—	—	12,374	101,280
Western Africa	185,435,990	—	—	12,078	44,543,084	78,524	44,543,084	1,036,222	32,801,436
Americas	39,194,276	130,103	9,607,137	5022	9,607,137	25,582	9,607,137	801,285	8,906,470
Northern America	2,685,122	9207	624,400	359	624,400	1777	624,400	25,982	257,878
Central America	9,007,506	40,516	2,254,084	1413	2,254,084	8087	2,254,084	166,208	780,315
Caribbean	3,439,056	9053	621,356	149	621,356	1278	621,356	252,818	1,221,427
South America	24,062,592	71,327	6,107,297	3101	6,107,297	14,440	6,107,297	356,277	6,646,850
Asia	579,347,344	4,486,883	344,195,895	195,480	344,195,895	918,554	344,195,895	12,219,732	114,335,466
Central Asia	10,986,896	38,152	2,099,490	1102	2,099,490	5346	2,099,490	56,111	548,841
Eastern Asia	165,473,380	2,452,793	162,739,830	96,363	162,739,830	498,988	162,739,830	442,160	8,039,210
Southern Asia	**326,303,601**	**1,477,785**	**142,467,519**	**79,171**	**142,467,519**	**318,717**	**142,467,519**	**10,146,318**	—
South-eastern Asia	37,545,555	—	—	8875	18,929,297	49,997	18,929,297	399,648	9,329,661
Western Asia	39,037,912	272,881	17,959,759	9969	17,959,759	45,506	17,959,759	1,175,495	14,998,180
Europe	16,241,452	88,129	8,019,723	4211	8,019,723	16,600	8,019,723	3,121,548	11,427,563
Eastern Europe	4,752,310	29,676	2,121,799	1257	2,121,799	6778	2,121,799	—	—
Northern Europe	247,311	497	39,692	20	39,692	103	39,692	26,587	54,135

(Table 1 continued)

Southern Asia	**326,303,601**	**1,477,785**	**142,467,519**	**79,171**	**142,467,519**	**318,717**	**142,467,519**	**10,146,318**	**—**
Southern Europe	8,875,054	47,738	4,855,172	2236	4,855,172	8752	4,855,172	1,120,143	6,560,893
Western Europe	2,366,777	10,218	1,003,060	698	1,003,060	967	1,003,060	1,199,130	1,862,640
Oceania	4,301,278	29,370	2,023,333	2372	2,023,333	8222	2,023,333	40	1367
Australia and New Zealand	3,977,140	29,052	1,992,243	2360	1,992,243	8166	1,992,243	—	—
Melanesia	23,173	204	23,173	8	—	36	23,173	40	1367
Micronesia	*****	14	1228	1	1228	3	1228	—	—
Polynesia	31,494	100	6689	3	6689	17	6689	—	—

Table 1.
Worldwide goat production (meat, milk, fat, skin, etc.) according to FAO, 2020.

3.1.1 Scientific classification (Taxonomic Position) for goat

Classification	Scientific name	Common terminology
Kingdom	Animalia	Animal
Phylum	Chordata	Vertebrates
Class	Mammalia	Suckle Young
Order	Ungulata	Hoofed Mammals
Sup order	Artiodactyla	Even-Toed Ungulata
Section	Pecora	Typical Ruminants
Family	Bovidae	Hollow Horned Ruminants
Subfamily	Caprinae	Sheep And Goat
Genus	*Capra*	Goat
Species	*C. aegagrus*	Domesticated Goat
Subspecies	*C. a. hircus*	

3.2 The history and immigration of goats following domestication

Historically, goats accompanied people in migrations and dispersing across the globe. They migrated to Europe and arrived at the far west and north edges of the continent about 5000 years before the present (YBP) [27]. Expansion eastwards to Asia and southwards to Africa occurred at the same time [28]. Goats were present in North Africa around 6000–7000 YBP [29], and in Ethiopia and the Sahara around 5000 YBP [30, 31]. The goats arrived in South-Saharan Africa, around 2000 YBP. In Asia, the evidence referred that, the goats were present in most areas of China around 4500 YBP [32] and moved further east and south thousands of years later. The goats arrived in Oceania and the Americas approximately during the fifteenth and eighteenth centuries jointly with European migrations to Americans [33].

There were waves of early migrations out of the domestication centre (DC) or Fertile Crescent (a crescent-form area of popular fertile land that is located in the middle east, extends from the Persian Gulf to the eastern Mediterranean through the Valleys of Tigris and Euphrates rivers) (**Figure 1**). This area was the centre of the Neolithic developing of agriculture since 7000 years BC, and the cradle of the Babylonian, Sumerian and Assyrian civilizations in the area that covers Northwest Iran and East Anatolia, ca; 10,500: 9900 (YBP) [16, 34], where, early domesticated goat followed the spread of farming and agriculture by radiating from the Fertile Crescent to Asia, Africa and Europe. Logically, the breeds from the regions near DC are expected to have retained partial ancestral diversity; thus, the Turkish goat breeds and Iranian goat breeds are similar to the wild ancestor (Bezoar breed) [35]. Moreover, one thousand generations ago, those original populations had larger similarities than recent breeds.

After a long time of so-known soft selection around two-hundred years ago, the case changed dramatically with the appearance of the concept of the breed [36]. The selection increased intensively in local breeds, followed by reproductive breeding between populations, thus, standardization of trait performance, all of these led to the fragmentation of the Initial Gene Pools (IGPo) [37]. A long period later, the pressure of selection has increased again through the utilization of artificial insemination (ArI), resulting in limited artificial populations with decreased effectiveness of population size, high trait performance and profound new phenotypic characteristics, for example trait-driven breeding for meat, dairy and cashmere [38]. As indicated by the diversity of ancient DNA (**a**DNA), the distinct Neolithic goat breeds from Southwest Asia owned a remarkable genetic structure [35]. These breeds characterized the populations in different areas surrounding DC, with early domestic goats from the east, west and southwest sides of the Fertile Crescent. The genomic analysis confirmed the relationship between those breeds and the populations from Asia, Africa and Europe [39].

The migration waves included sources of distinct breeds from that left their traces in the partitioning of diversity between countries and continents. Colli et al. [39] reported that regional gene pools were further promoted through the high levels of gene flow that characterize the breeds in large regions within Europe and Africa. In Europe, goat breeds are partitioned locally by regions corresponding to the central Mediterranean, eastern Mediterranean and eastern Alps together with continental Ireland and France and North Europe [35]. In Africa, population clusters correspond to East, West, Southeast, Northeast Africa and Madagascar. The geographical distribution of the African gene pools overlaps with those of the populations that share similar morphological characteristics; among them, African dwarf populations in central-Africa have short-eared Trypanotolerant goats, Northeast African populations have lop-eared goats, Small East African populations have short-eared Trypanotolerant goats scattered throughout the southeast and the far south has lop-eared goats [39]. Subsequently, the trading and migration led to an increase in populations and breed exchanges and movements, generating a reduction of genetic partitioning and resulting admixture [39].

A recent study by Colli *et al*. [35] confirmed that South American goat breeds are occupying an intermediate position between breeds from South Europe (Spain) and Northwest Africa. On the other hand, there is a rapprochement between some breeds from Australia, namely Cashmere and Rangeland and Turkish breeds, whereas the Pakistani breeds were separated from the rest of the populations of West Asia. In Africa, there are many sub-groups corresponded to East Central, Southeast, Northwest Africa and the Canary Islands. In Europe, clusters of populations consistent with North Europe (Norway, Netherlands, Iceland and Finland), South Europe (Central, South Italy and Corsica) and Western Europe (France, Ireland, Sardinia, Alpine breeds and Spain) were revealed. Romania Balkan breed had an intermediate position between West Asian populations and South European (Central Italy). Also, several Pakistani and European breeds were individually assigned to distinct clusters. There is a strong introgression originally in Africa with South America, Spain and Southern Italy breeds. However, previous genetic investigations uncovered the variety of sheep breeds worldwide revealing a low degree of differentiation of 2.98% among varieties between continents and sharing high levels of haplotypes [40], while cattle breeds (*Bos taurus*, *Bos indicus* and *Bos javanicus*) possessed 13% of all variation, but were 3.2% for taurine cattle, between African and European breeds [38, 41].

Three large-scale studies, two of them depended on microsatellite markers, and the third was based on the high-density SNPs [20] confirmed the occurrence of many regional gene pools, jointly with a clinical reduction in variability from DC in Southwest Asia towards northern Europe, Indonesia and China [42, 43].

Another investigation utilizing the mitochondrial DNA technique (mt-DNA) [44] confirmed that the high frequency (> 90%) and worldwide distribution of haplogroup

(A), associated with geographical differentiation between continents, was uncovered by chromosome (Y) haplotype analyses [28, 45]. Furthermore, the widely distributed haplotypes (Y1B) and (Y1A and 2A) have been confirmed in Near East, North Africa and Europe, haplotype (Y2C) in Turkey and haplotype (Y2B) in Asia [46]. A recent investigation utilizing **a**DNA data succeeded to structure strongly, the nuclear molecular and the mitochondrial variation of Neolithic goat flocks [39]. This presented direct support to the hypothesis that several wild origins existed for early domesticated goat populations as was already found from mtDNA data tests [22, 44] and further refers to that recruitment from different local Bezoar breeds was extensive [47].

3.2.1 Distribution of goats to the different regions of the world

Since domestication, goats have established a large geographic range because of their adaptability to hard climatic conditions and poor diets [48]. There are more than 1000 goat breeds have been surveyed in the world in 2012 [49]. In 2020, the Asia-Pacific region possesses the greatest share of the goat population followed by the African region **(Table 1)**. Both regions harbour more than 90% of the world's population [50], followed by Europe, the Americas and Oceania [9, 51]. Worth mentioning, the main hotspots of global goat diversity and differentiation are in Africa, Asia and some European countries [9, 19]. Skapetas and Bampidis [51] confirmed that about 95 per cent of the goat breeds throughout the world are found in developing countries, especially in Asia and Africa. Asia holds first place with 579,347,344 heads of different goat breeds **(Table 1)**, which forms 59 per cent of the world breeds. Asian countries contribute a considerable amount of goat products to the world economy. Per cent contribution of the goat products produced in Asia to the world production is 70.7% for meat, 58.3% for milk and 76.5% for skin. Goat production is considered to be very important for its contribution to the development of rural area in many countries. They have performed agricultural, economic, cultural and even religious roles and form important meat, fibre and milk resource [52, 53].

Goat breeds are globally distributed to every ecological area, though concentrated in the tropical developing countries and dry zones [54, 55]. Diversity in the climate and geography jointly with factors of traditions and history led to the development of a large variety of goat populations, which were developed later to the modern goat breeds [19].

The genetic structure of small ruminants especially goats reflects their domestication formation into different breeds [15]. The history of genetics for goat and sheep has been investigated utilizing three major sources of variation at the level of genomics: mitochondrial genome, Y chromosome and autosomes. The mitochondrial genome for goats has proven highly informative for studies into domestication, with results of haplogroups for several breeds [56, 57]. Recent investigations have tested collections of small ruminants from northern, southern Europe, and the Middle East, where, the facilitated tests of genetic partitioning through the globe. Interestingly, the breeds of southern European displayed much genetic differentiation compared with those of northern European [58, 59].

3.2.2 Modern domestic goat

Man domesticated goats along with many other species of animals since ancient centuries. The newest genetic analysis (GA) confirmed that there is archaeological evidence that the wild Bezoar ibex *Capra Aegagrus* of the Mountains of Zagros is likely the origin of almost all modern domestic goats today [60]. However, the morphological and behavioural characteristics of modern domestic goats have changed when compared with the progenitor of wild Bezoar goats [61]. The modern goat exhibit a more docile demeanour, variation in coat colour, reduction in body size and the ability to adapt after domestication and breed formation, which have left detectable selection signatures inside the genomes [62, 63].

3.2.3 Natural selection (NS) and artificial selection (AS) in goat

Natural selection (NS) has a necessary role in selecting the species that have high adaptability to changes in environmental conditions. Side by side, both NS and artificial selection (AS) have been applied widely to many livestock species to achieve more target phenotype traits [64]. Goats have been selected for domestication, since 10,000 years ago [22, 61]. The process of selection resulted in the differentiation of breeds that are characterized for the production of meat, milk or fibre, or multipurpose breeds in many different regions of the world [64].

The strategies of NS and AS imposed pressure on a region of genomes that control some traits such as meat, milk and fibre, in addition to many important characteristics, such as reproduction, adaptation to extreme environments, behaviour, body conformation (BC_F), resistance to parasites and diseases [64].

3.3 The vital role played by goat

The domestication and adaptation of wild goat to different environments and subsequent intensive trait-driven selection, inbreeding and crossing have led to intermediate breeds and phenotypic purification for the high-quality production of meat, dairy, cashmere, … etc. [65].

3.3.1 The meat of goat

Total goat meat production reached 6,142,140 tonnes in 2020 throughout the world. Based on a comparison of more than one hundred-sixty countries in 2020, China ranked the highest in the production of goat meat with 4,825,000 tonnes followed by India and Australia. On the other end of the scale was Singapore with 32 tonnes, Seychelles with 22 tonnes and Suriname with 20 tonnes. This total is 1.51% more than that in the last year and 15.2% more than ten years ago. Historically, total goat meat production reached an all-time high of 6,142,140 tonnes in 2020 **(Table 1)** and an all-time low of 6,032,000 tonnes in 1961. The average annual growth amounted to 1.69% increased since the 1960s. In 2020, goat meat was the world's 381st most traded product, with a total trade of 7,420,000,000$. Between 2019 and 2020 the exports of sheep and goat meat decreased by −7.21%, from 7,990,000,000$ to 7,420,000,000$. Trade in goat meat represents 0.044% of total world trade.

Goat meat is characterized as lean red meat with favourable nutritional elements [66, 67]. It has a coarser texture, somewhat darker colour and distinctively different flavour and aroma than mutton [68, 69]. The smell and taste of goat meat are similar to the meat of springer sheep lambs. The results of sensory investigations marked goat meat to be different from mutton but absolutely not inferior to lamb [67]. Goat meat tends to be less juicy than lamb predominantly due to its reduced fat content [70]. Its special flavour is related to the presence of 4-methylnonanoic acid and 4-

methyloctanoic acid [71, 72]. Also, branched-chain fatty acids (FA) may contribute to the typical goat meat flavour [73, 74].

3.3.2 The milk of goat

Over one billion goats live worldwide and due to expanding demand for milk, goats raised primarily for milk production are increasing in number. The total number of dairy goat reached 220,921,370 heads, while the total goat milk production reached 20,629,610 tonnes in 2020 throughout the world [75]. Most dairy goats are produced in Asia, 114,335,466 heads produced 12,219,732 tonnes of goat milk **(Table 1)**. A global picture of the dairy goat sector sheds light on the lessons learned in building successful modern dairy goat industries. In Europe, especially in France, goat milk is the most organized market. Goats are primarily raised for milk production, mainly for industrial cheese making, but also for producing traditional cheeses on farms. Because of rising consumer demand, strong prices and climate change, there is an emerging market for goat milk in countries with no goat milk traditions, such as China, United States and New Zealand [76, 77].

The milk production of goats presents about 2% of the total annual supply of milk worldwide. This milk has very small well-emulsified fat globules that make it does not need to homogenization. The butter from the goat milk is white because of converting the yellow beta-carotene to the colourless vitamin A [78]. The goat milk composition includes water (88.9 g), protein (3.1 g), fat (3.5 g), carbohydrates (4.4 g), sugars 'lactose' (4.1 g), cholesterol (10 mg) calcium (100 IU), saturated fatty acids (2.3 g), monounsaturated FA (0.8 g) and polyunsaturated fatty acids (0.1 g) per 100 grams (g) [78, 79].

3.3.3 The reproductive traits of goat

3.3.3.1 Female fertility

It has been known since domestication that goats are seasonally polyestrous which means they reproduce naturally at certain times of the year. There are several factors that affect this characteristic, including daylight hours (photoperiod), altitude and nutrition [80].

The breeding season of goats will be shorter at latitudes farther from the equator. The availability of nutrients and the environment will determine the presence of oestrus in latitudes closer to the equator. Oestrus cycles in goats last on average for 16 days, with a high frequency of short cycles occurring during reproductive seasons and in young animals [81]. Oestrus lasts on average 36 hours but can vary between 24 and 48 hours depending on factors such as age, season, breed and presence of a male [82].

Understanding goat reproduction is crucial to increasing productivity, which is largely a function of pregnancy rate, the number of offspring born and weaned and the frequency of kids reproducing. Goat reproductive management produces a high level of fertility (90% and more) and optimum litter size (twins and triple) with a high rate of survival to weaning. All of the above processes will help producers to manage their herd more efficiently and breed their does to produce kids that will fit a specific market niche to command a maximum price. Worth mentioning, the major constraints to the reproductive management of goats are lack of data on the reproductive performance, especially of domestic goat breeds and the seasonal nature of breeding [82].

3.3.3.2 Male fertility (Semen production and quality)

There is a seasonal effect on male fertility (semen production and quality) in goat. Significant seasonal effects were reported in the Murciano-granadina, Alpine, Saanen and Damascus, Payoya, Damascus, Rayini, Zairi, Jakhrana, Blanca Andaluza, Anglo Nubian, Brazilian, Spanish breeds such as 'Payoya goat' and Peshawar dairy goats [82]. However, semen quality for goat has a high-quality level in different seasons probably due to the high reproductive ability of males [83].

3.3.4 The fibre (cashmere/ mohair/ hair/ cashgora) of goat

There are many inhospitable and marginal agricultural areas in the world where goats are kept and fibre is an important product in those areas. Cashmere, mohair and hair are three notable goat fibre products. In addition, a hybrid type called cashgora has characteristics between cashmere and mohair. The quality and yield of mohair (produced by Angora goats) are influenced by nutrition and are better suited to more staple environments that do not experience dramatic fluctuations in food availability. Cashmere growth, on the other hand, is remarkably insensitive to the nutritional influence, and may successfully be produced in harsh, continental climates. Goat hair is used, particularly in arid areas, for the manufacture of coarse cloth, tent fabrics and ropes. Goats are able to utilize vegetation dominated by woody species, such as brush range or veld, which may be unpalatable to other grazing livestock. Their diet selection behaviour, when present at an appropriate stocking rate, can be used to achieve vegetation management objectives, for example sustainable brush or veld management, weed control or pasture improvement. Cashmere goats are produced primarily in highly extensive systems and by subsistence-level pastoralists and nomads. The major producing countries are China, Mongolia, Iran and Afghanistan. Systems have been developed since 1970 for cashmere production in Australia, New Zealand, United Kingdom and United States which together represent some 9% of total world production. Primary producers of mohair are South Africa, United States, Turkey, Lesotho and Argentina. Smaller numbers of mohair goats are kept in Australia, New Zealand, France, Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan, Denmark, Spain and United Kingdom [77, 84].

Most goat breeds possess insulating hair covering the skin, a desirable fibre for the textile industry named cashmere or pashmina (a Persian word that means fine wool) [84]. The cashmere goat breed produces a large quantity of high-quality hair which is one of the most expensive fibres commercially produced [84]. The fibres of goats and sheep were used in many desert areas around the world to make houses built from fibres, especially nomadic caravans (**Figures 2** and **3**).

3.3.5 Using goat for land clearing

Goats have been used to clear vegetative residues for many centuries. They have been described as 'biological control agents' and 'eating machines' [85, 86]. In North America, goats were used in a conservation grazing programme (1991) to clear dry bushes from California hillsides to avoid being endangered by wildfires. Since goat herds are being hired by public and private agencies to perform conservation grazing

Figure 2.
The houses of goat's fibre in many desert areas in the middle east including ('El-Hammam city, Matrouh, Egypt', 'Moroccan desert, Morocco', 'Zulfi City, Saudi Arabia') (Developed by the authors).

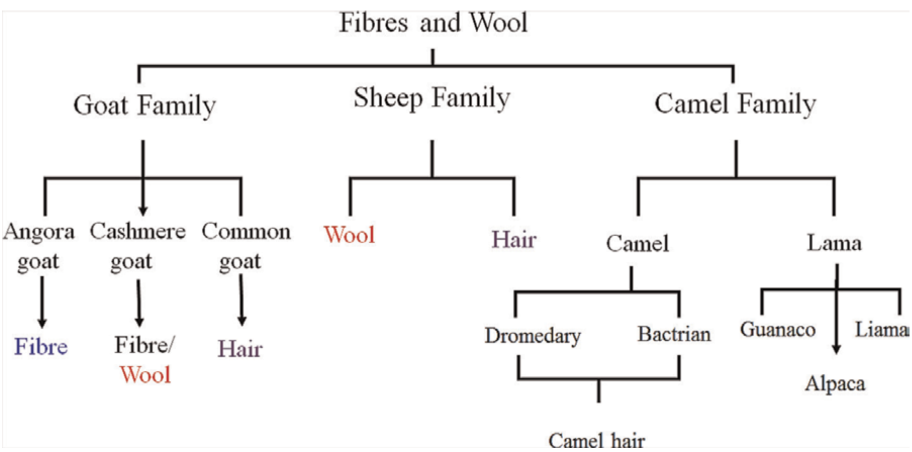

Figure 3.
The various types of fibres/wool are most commonly used for applied purposes (Developed by the authors).

such practice has become popular in the Pacific Northwest. Goats succeeded to remove invasive plant species that cannot be easily removed by people, for example thorned blackberry vines and poisonous oak [86–88].

3.3.6 Using goat for medical training

Because goat physiology and general anatomy are not too different from that of humans, many institutes use goats for training combat medics in some countries. In the United States, goats have become the main species used for this purpose after the Pentagon phased-out using dogs in the 1980s [89]. Moreover, modern mannequins are utilized in the training of medical scholars on simulating the behaviour of the body. The trainees feel that when goats exercise they provide a sense of urgency that only true life trauma can provide [90].

3.4 Biodiversity of Goat Genetic Resources (GGR)

In view of the declining diversity in animals, awareness has arisen for the study of variation among and within goat genetic resources (GGR). In livestock, animal genetic resource diversity is expressed among and within breeds. Such diversity is of great importance in planning and implementing genetic improvement programmes [1, 2]. Genetic variation cannot be quantified only by studying morphology but also by using molecular techniques which makes it more reliable. These techniques are now widely used to study the biodiversity between populations. Variation is the substrates that natural or artificial selection can act on, therefore, genetic variability and then biodiversity is fundamental to the long-term survival of natural or domesticated populations [3].

Molecular genetics can be used to enhance the understanding of how genetic variation is portioned within and between breeds of livestock and this can play a necessary role in animal breeding programmes and genetic improvement strategies [2, 4]. A breeding goal, especially in small populations, should also sustain genetic variability which is important for selection and breeding strategies. At the molecular level, clarification of the population structure can be achieved by the highly variable loci that provide a large amount of information on individual genotypes [5].

According to one measurement of biodiversity, the goat has the highest degree (0.9) in comparison with some livestock species, that is 0.8 for cattle and 0.5 for buffalo [6]. This index of biodiversity depends on the number of breeds per million of a population of the species. Most of the breeds in developing countries are named 'local' because they are not characterized due to the lack of resources needed for characterization or measuring biodiversity [7]. For many years, breeds have been studied according to their phenotype as an indicator of biodiversity between and within populations. Several studies used phenotypic expressions such as blood protein polymorphism, isozyme variability and blood plasma to assess genetic variation, genetic distances, heterozygosity and genetic structure. This brought in some help for animal breeders to perform genetic improvement programmes and selection [8].

3.4.1 The importance of studying genetic diversity in goat

Goats can withstand hard conditions and survive primarily through scavenging for nourishment, while requiring small investment for maintenance. In addition, in the case of investment capital availability, goats are able to yield handsome returns. Thus, goats are present in a wide variety of production systems under extreme environments. Also, limited formal crossbreeding and few cosmopolitan goat breeds are available compared to other species. For these reasons the best ways for studying the adaptation and genetic diversity of goats are similar [10, 35].

3.5 Modern versus old strategies to enhance goat genetic performance

3.5.1 Old strategies to enhance goat genetic performance

Since domestication, farmers and breeders have been attempting to define target traits which may pass to the next generations and depend on the information on pedigree or on measuring of phenotype in order to make decisions on small ruminants to be kept or mated in the farms. These decisions have been important and effective to make necessary changes in the characteristics of the animals, making these species more economically efficient [13, 91].

The selection programmes which depended on the classic approach (classic breeding/ phenotype characteristics only) have been very useful and successful in their old-time, but they face many limitations and known defects because of the use of phenotypes only in selection: 1) the high cost and extra time to make records on phenotypic traits value. 2) There are many target traits that appear on female-only such as milk yield, 3) some traits take a long time to measure such as longevity. 4) Other traits need the slaughtering of individuals such as meat quality. 5) Resistance traits require the animal to get sick when exposed to the disease in order to measure disease resistance [92–95]. All these and many other obstacles such as phenotyping constraints limit genetic progress.

On the other side, there is often little focus on breeding goats by most development organizations. Smallholder farmers' indiscriminate breeding practices often result in negative genetic effects due to the lack of continuous, structural and established genetic improvement programmes. The result is decreased genetic merit of goats leading to a decline in productivity. This results in an inadequate availability of improved breeds for multiplication. Therefore, a systematic scientific approach for breed improvement aiming to increase the productivity of goats through genetic improvement is indispensable for increasing the impact [96, 97].

The most important criteria that were utilized to identify some individuals from males or females to be utilized for breeding and production are the assessment of their breeding value (BV) to focus on target traits in the next step. The BV is defined as all of the additive effects in all loci that contribute to the QTL deviating from the mean of the population [98].

In the last few decades, genetic techniques and sophisticated statistical analysis have allowed breeders to obtain estimates for the genetic values (GV) of their herds, depending on pedigree information and phenotype [99, 100], utilizing the mixed model procedures, to obtain the Best-Linear Unbiased Prediction (BLUP) of Breeding Values (BVs). This way is globally utilized for the evaluation of GV in all commercial livestock species industries. In several investigations, using estimated breeding values (EBVs) to arrange matings and making decisions has contributed significantly to genetic progress and consequently to the profitability of goat and sheep raising [101, 102].

The population mean is what breeders aim to improve. The second factor is that progeny receive 50% of their alleles from mother and 50% from father, the records of phenotypes, especially for target traits and traits that are genetically correlated with them have been used as the only source of information to estimate BV for selected candidates. To do this, the statistical BLUP methodology of the mixed linear model can be successfully utilized. That method depends on the information from phenotypic records, which were not only collected from the individual itself but also from its relatives to maximize the accuracy of the resulting EBV [103, 104] (**Figure 4**). Selection theory and statistical models utilized in breeding programmes

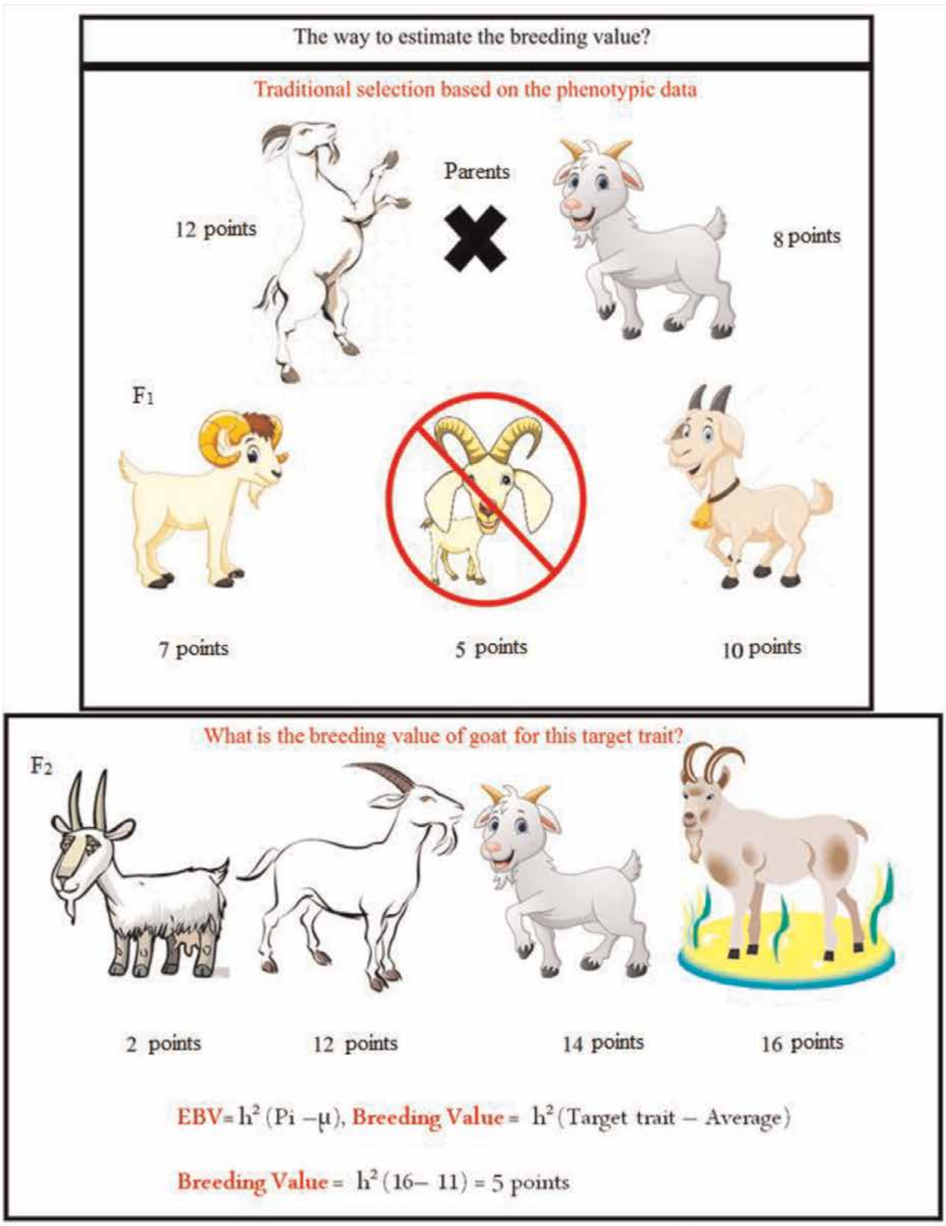

Figure 4.
Estimation of breeding value (EBV) utilizing traditional methods (traditional selection) (Developed by the authors).

depend on the known infinitesimal model of quantitative genetics [98]. This model assumes that the traits are related to an infinite number of genes that have additive and minor effects [92].

However, animal breeders built up a big deal of experience, investigating opportunities and making conclusions to obtain early measurements for target traits on selection candidates, which may be utilized to improve the accuracy of EBV estimation at an early age. One of the important early applications was utilizing the success in blood groups as a marker for disease resistance in chicken selection [93].

A substantial rate of genetic progress has been achieved for many quantitative traits by selection in livestock populations including goat breeds utilizing EBV derived from genotypes and phenotypes [105, 106]. This approach did not require information on genes, loci or signatures of selection (SS) that influence the target traits. Meanwhile, the application of molecular genetics tools for quantitative trait selection processes in the past decade was too expensive.

On the other side, the availability of new molecular techniques such as high-density SNP panels/chips and Whole-Genome Sequencing (WGS), and thus the genomic selection (GS) approach may have a good impact on livestock genetic improvement including goats. Additionally, the methods of genomic evaluation are able to improve substantially the accuracy and effectiveness of Genome Enhanced Breeding Values (GEBV) estimation in goats and thus accelerate the response for selection. The accuracy of the methodology that utilizes genomic prediction such as genomic best linear unbiased prediction (GBLUP) and best linear unbiased prediction-SNP (BLUP-SNP) is limited when the target family or population is small [107, 108], though the application of GBLUP increased accuracy of EBV than pedigree-based BLUP [109].

3.5.2 Modern strategies to enhance goat genetic performance

The development of next-generation sequencing (NGS)/ WGS since 2007 has allowed for obtaining the genome sequencing [109] of goat [110], sheep [111], cows [112] and buffaloes [113]. Thus, it became feasible to develop high-density SNP chips, for example the (Goat SNP K50 Bead-Chip), which contains 53,347 SNPs [114] and the (Ovine 600 K SNP chip), which contains 606,006 SNPs. The availability of such high technologies has allowed the utilization of genome-wide results for animal breeding improvement plans [40, 115].

In this regard, molecular tools had revolutionized animal species breeding around the world through increasing genetic gain compared to old or traditional methods. The improvement was achieved for many livestock products such as beef and milk from cattle utilizing both traditional and high technology methods; however, there is a lack of knowledge concerning small ruminants [9, 95, 116]. Additionally, getting Genome Enhanced Breeding Values (GEBV) at early age to apply selection on young individuals prior to getting the data of extensive progeny had crucial effects on breeding programmes in many species [117].

GS had revolutionized animal species breeding including goats, around the globe. Therefore, this work aimed to discuss the evolution and vital role of advanced molecular tools to develop livestock populations, especially goat breeds worldwide. Also, to scan topics that are necessary for the successful application of genomic results and review the candidate genes, SS and quantitative trait loci (QTL) influence important traits in livestock populations worldwide and present the role of GS which depends on knowledge of the behaviour of the phenotypic traits along with information about the genome, also taking the spotlight on the relationship between economic traits and genetic differentiation in goat.

3.5.2.1 Assess the genetic resources of indigenous goat populations

Several indigenous goat populations are threatened with extinction because of taking their places by cosmopolitan breeds; however, these breeds might represent unique valuable resources of genotyping. Recent studies estimated that 18% of indigenous goat breeds worldwide are threatened or extinct. Thus, the characterization and determination of genetic differences between and within indigenous goat populations is a potential tool to help the rapid improvement of economically important traits. Side by side, the characterization and determination of WGS variation in livestock species are possible by utilizing new technologies of sequencing [62].

Therefore, it is important to assess the genetic resources of indigenous goat populations, and, thus, manage those breeds sustainably in addition to present zootechnical ways that take into consideration the preservation of goat genetic resources. This is probably useful at least under the current changes in the global environment [118]. To accurately determine and characterize resources of goat genetics, it is important to access the variety of data in WGS. This would help the identification of genes and mutations of alleles related to different environmental conditions especially, those potentially representing a necessary adaptive role [119].

3.5.2.2 The concept of modern genetic improvement

The genetic improvement in livestock domesticated populations utilized for multipropose production includes mainly the selection of females and males that are mated to produce next generation that shows performance better than the average of the current parents. The genetic improvement that uses the fundamental foundations of old breeding strategies, such as BV side by side with modern genetic techniques/tools is a promising approach for improvement [92].

3.5.2.3 Quantitative traits

By using special statistical methods, researchers and breeders can locate chromosomal regions that contain many genes contributing to variation in a quantitative trait of interest in a population by starting with its phenotype (phenotypic) and moving forward to its genotype (genotypic). Since phenotypic performances partially reflect the genetic values of individuals in the breeding process, many traits of interest in animal breeding show quantitative inheritance. QTLs and environment interactions define a quantitative trait's genetic variation. On the other hand, it is common for quantitative traits to be controlled by several genes and in some cases, hundreds, even thousands of genes, all in conjunction with the environment. Two of the most popular methods for mapping QTLs and exploitation of molecular markers in animal breeding are linkage analysis and association mapping. A subset of markers is found associated with one or more QTLs that regulate the expression of complex traits. There is currently an optimistic assessment of the possibilities of marker-assisted selection (MAS) based on the identification of QTLs that explain a significant proportion of phenotypic variance by QTL mapping, which may push strongly towards achieving the goal of genetic improvement [98].

3.6 Molecular (Modern) tools for measuring biodiversity

The development of molecular techniques in the last five decades facilitated studying biodiversity in goat genetics. There are three generations of molecular tools: 1) the first generation includes random amplification of polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), restriction fragment length polymorphism (RFLP), single-strand conformation polymorphism (SSCP) and microsatellites (MST) / simple sequence repeats (SSRs). 2) Second-generation includes mitochondrial DNA (mtDNA), DNA microarray (biochip or DNA chip), the low and high-density of SNP chips and WGS and 3) third-generation single-molecule real-time (SMRT) [82, 120].

Worth mentioning, the new concepts in goat genetics and the breeding sector highlight the necessity and seriousness of characterizing and determining novel polymorphisms, which are associated with important traits. Detailed studies have been done and others are still underway to re-design genomic maps to understand the effect of allelic variants on the analysis of performing linkage and quantitative phenotypes to accelerate genetic improvement utilizing different molecular tools in goat breeding programmes [9, 95, 121].

In order to identify strategies of conservation and monitor genetic diversity, many investigations on molecular markers such as SNPs panels [122, 123] were carried out. Nowadays, the availability of panels for SNPs eased the testing of animal genomic diversity [124, 125]. These panels have replaced microsatellites in detecting genetic diversity and parentage assignment (PA) in many species [126]. The SNPs approach is one of the most typically utilized classes of a genetic marker. Through the second phase of the Hap-Map project, 4.4 million SNPs have been genotyped in the human genome [127]. In dogs, approximately 2.5 million SNPs have been found [128], in chickens, approximately 2.8 million [129], in mice, approximately 8.2 million [130], in cows, approximately 60,000 [131] and in goats >41 million [132]. In humans, genome-wide association studies (GWAS) have used these markers to discover genomic regions or sequence variants associated with 40 complex diseases [133].

In different species, the developing of the NGS permitted the check of the sequencing of the goat [110, 134], sheep [111], cattle [135, 136], buffaloes [137], deers [138], chickens [139] and pigs [140]. The first SNP chip 50 k Bovine having more than 50,000 SNPs was available in 2011. It was built utilizing ten geographically and biologically different breeds. On the other side, the International Goat Genome Consortium (IGGC) for goat genome affairs was established in 2012 [141], with primary goals of improving and increasing the tools for extracting genomic information on goat genetics and supporting the international efforts to develop the 52 K SNP chip known as commercial Illumina [142], in 2013 [114] by combining genome-libraries and WGS from eight populations (breeds) from Asia and Europe [141]. The first assembly of the genome of a goat was released by Dong *et al.* [110]. The identification of 12 million SNPs allowed the design of 53 K SNP and 54 K SNP chips that are extensively utilized globally [114]. A 54 k cattle SNP chip was applied to characterize the genome of cattle and buffaloes [143]. More recently, there are 60 K SNP and 62 K SNP chips [144]. Nowadays, there are chips of 40,000 to 65,000 SNP are available for most livestock species, including cattle, buffalo, sheep, goat, horse, poultry and pigs, and in other species, these chips are still under development [92]. It may provide powerful means for the direct discovery and identification of traits associated with sequence variations underlying the molecular mechanisms of adaptation and domestication by using suitable statistical methods [145].

3.7 Outcomes of utilizing advanced molecular tools in goat breeding

3.7.1 The high-throughput SNP (SNP panels)

The recent investigations proposed a new method of selecting SNP even when utilizing a limited number of individuals or breeds [146, 147]. The AdaptMap project initiative has collated 53 K genotypes from more than 140 breeds from 17 countries, providing the international dataset for goats. The main goal was to select a panel of SNPs that has high performance for the parentage assessment and assignment for 91 populations. Interestingly, two approaches were utilized for this aim: the first one is an approach that depends on the detection of SNPs for proving the relationship between individuals, and the second is an approach that depends on selecting the SNPs that maximize the minor allele frequencies (MAF) in the largest possible number of breeds as represented by Talenti *et al*. [126] who selected a panel of SNPs suitable and readily applicable for PA and assessment for a large number of goat breeds around the globe. Therefore, these SNPs were validated on a large data set involving Alpine and French Saanen goat populations.

The Caprine-SNP50k Bead-Chip was used to investigate and compare several Swiss goat breeds, and SS were identified in the regions that affect variation in milk composition, growth and coat colour [148]. More recent advances such as Goat 50 K SNP Bead-Chip offered the opportunity to identify regions in genomics that have undergone selection. There are few investigations utilizing the arrays of SNP focused on local goat breeds such as Moroccan and Italian [19, 62]. Lashmar *et al*. [66] reported that the Goat SNP 50 Bead-Chip has a marked positive change at the molecular level for small ruminant species. Now, the commercial 50 K SNP chips have been available for about 6 years [114] and have already been utilized on the national, regional and continental levels to explore goat diversity [20, 149]. Similar advances in sheep [150, 151], cattle [152, 153], pigs [154, 155] and chickens [153] have defined genes related to undergoing positive selection and contributed to phenotypic variation.

Brito *et al*. [64] reported that 1151 individuals belonging to nine breeds genotyped by the 50 K Bead-chip were identified for many genes related to important economic traits. Others were identified and found related to many traits such as milk protein and somatic cell count score, *FAM13A* [156, 157], reproduction traits, *MEF2BNB* [158], *CACNB2* [159] and *CYP19A1* [64], the efficiency of feed conversion, *KIAA1211* and VAV-3 [160], adult body mass, *GPR-61* [161], conformation traits, *RNF-157* [162], abdominal fat deposition, *PRPSAP-1* [163], metabolism of liver fat, *TM6SF-2* [164], the fatty acids in milk, *CDH-12* [165], heat-tolerance, *GNAI-3* [166] and ear morphogenesis WNT5A gene [167].

3.7.2 Scanning the Mitochondrial DNA (mtDNA) sequence

NGS was used to detect the mtDNA variants [168, 169]. The mt-DNA has represented the most informative genomic element to investigate diversity in all closely related livestock and individuals within many species [170], because it displays the maternal inheritance relatively rapid against evolution rate and without recombination [18, 57]. Also, mt-DNA is one of the most useful tools/ approaches in molecular phylogenetics and population genetics [171].

Practically, mt-DNA variation or mutations create differentiation in the efficiency of the oxidative phosphorylation pathway and consequently cellular energy production thus variation in the performance [172]. The molecular tools allowed to discover these variations in mt-DNA and built an association with the performance of different traits in many livestock species [173].

Concerning mt-DNA of goats, the phylogeny of domestic goats elucidates six credible maternal haplogroups of domestic goats worldwide, namely; A, B, C, D, F and G. However, the classification and ownership of some low-frequency mt-DNA haplogroups in several small geographic regions remain controversial. [174]. The probable origin of mt-DNA haplogroup (A) could be Eastern-Anatolia, while haplotypes A and C have been detected in ancient goat samples (from an early Neolithic site) in Southern France. Meanwhile, haplotypes B, D and G have been found in Eastern Anatolian and Northern Iranian bezoars. Also, there was domestication marked by haplogroup C in the easternmost [175].

mt-DNA is an extensively exploited tool for the evaluation of evolutionary relationships and genetic diversity in goats. In this regard, the popularity of mt-DNA for phylogeographic investigations has been attributed to its remarkable properties, such as maternal inheritance, high copy number, higher mutation rate without any recombination and the clock-like nature of its substitution rate in goats and other species [175]. Also, the Displacement-region (D-loop) in mt-DNA is characterized by highly polymorphic regions (Hypervariable-region *I* and *II*) and has been particularly informative in explaining the origins of several livestock species including goat [174, 176].

3.7.3 Identification of candidate genes related to important traits

A big number of candidate genes have been discovered and identified in different species utilizing molecular tools [177]. Numerous studies reported the discovery of hundreds of genes in different animal species since the release of the genome sequence reference **(Table 2)**. There is a relationship between candidate genes and economic traits, such as reproduction, production traits and disease included dozens of genes [165, 183], and the effects of those candidates vary as follows: 1) several candidates have associations with the physiological and metabolism pathways, for example *IGFBP-3* [116], *GH* [184], *GHR* [185], *IGF-I* [186], *CAST*, *CAPN-1* [187], *POU1F1* [188], *LEP* [189] and *MSTN* [190, 191] genes that are crucial for birth weight, weaning weight, growth traits, bone formation, muscle growth, body size and meat quality. 2) Other candidates have an association with fertility, infertility and reproduction, proliferation and sex-determination, for example *MTNR-1A* [192], *FOXL-2* [193], *AMEL* [194, 195], *SRY* [193, 196] *BMPR-1B*, *GDF-9* and *BMP-15* [95] genes. 3) The third part of genes is candidates for milk composition and milk yield traits, such as the family of casein genes [197–199]. Worth mentioning, genes related to casein formation in milk protein are already utilized in breeding programmes [200].

No.	Species	Number of QTLs	Number of publications	Concerning Traits	Refs..
1	**Goat**	128 QTLs	6 publications	Represent 25 different traits	[178–182]
2	**Chicken**	16,656 QTLs	376 publications	Represent 370 different traits	
3	**Sheep**	4416 QTLs	226 publications	Represent 266 different traits	
4	**Cattle**	193,216 QTLs	1111 publications	Represent 684 different traits	
5	**Horse**	2636 QTLs	106 publications	Represent 65 different traits	
6	**Pig**	35,846 QTLs	773 publications	Represent 693 different traits	

Top Goat QTL associations in the Database 2022			
No.	Traits		Number of QTL ***Refs.***
1	**Udder dimensions**	Udder depth	**30**
2		Teat number	**17**
3		Udder width	**17**
4		Fore udder attachment	**8 Goat QTL Database 2022**
5		Medial suspensory ligament	**4**
6		Teat placement	**4**
7		Teat diameter	**2**
8	Milk	Milk fat yield	**2 Goat QTL Database 2022**
9		Milk protein yield	**2**
10	**Body dimensions/ measurements**	Body weight	**9**
11		Chest width	**5**
12		Withers height	**4**
13		Body depth	**3**
14		Rump length	**2 Goat QTL Database 2022**
15		Rump width	**2**
16		Cannon bone circumference	**1**
17		Rear leg placement—rear view	**4**
18		Rear leg placement—side view	**2**
19		Angularity	**4**

Table 2.
Number of QTLs for many species based on animal QTL database updated to 2022.

4) The fourth part is related to fibre (hair/cashmere) traits, such as *FGF-5* [77], *IGFBP-7*, *MC1R* [201] and *KAP* [202] genes, which are vital to several characteristics of fibre, for example hair length (short, medium or long), hair colour (black, white or brown, …), hair colour pattern (plain, patchy or spotted), hair type (straight or curly) and hair appearance (dull or glossy). 5) Also, part of these genes is related to the immune system and disease resistance, as *MHC-DRB3* and *MHC-DQA2* genes [203], as well as Tmem-154 gene is related to resistance to (MAEDI-VISNA) [204], *Prp* gene is related to scrapie resistance in goat [204] and sheep [205], and *Socs-2* gene is related to the susceptibility to mastitis [206]. Worth mentioning, *Fec-L* and *Prp* genes in worldwide sheep, and *α-s1-casein* gene in French goat are especially used to pre-select candidates for progeny testing [165].

Also, utilization of advanced molecular tools resulted in mapping many useful individual genes in small ruminants [207, 208], dairy and beef cattle [209, 210]. Also, veterinary tests utilized advanced molecular tools for the diagnosis of genetic diseases, such as Deficiency of Uridine Monophosphate Synthase (DUMPS), Complex Vertebral Malformation (CVM) and Bovine Leukocyte Adhesion Deficiency (BLAD) in cattle which are tested to find out if the seed stock bulls are either carriers or non-carriers of these autosomal recessive mutations [211, 212]. Small ruminants individual testing for *Prp* gene associated with scrapie have been identified by molecular tools [213, 214].

3.7.4 Detection of Quantitative Trait Loci (QTL)

In the above molecular tools, the gene related to the trait of concern could have been either a single gene with a large effect which is known as a major gene [95], such as genes affecting, skin-tone and coat colour '*KIT* gene', polledness and double-muscling '*MSTN* gene', or could be one of several genes associated with a quantitative trait known as minor gene, such as genes related to growth, milk yield and wool quality [116]. The loci that affect a quantitative trait are termed QTL or Economic-Trait-Loci (ETL). By another meaning, a QTL is hypothesized as a specific region on a chromosome containing several genes that make a significant contribution to the expression of a quantitative/complex trait. In populations that had effective improvement programmes for many generations, MAS most likely will be for QTL rather than for major genes, since major genes with large favourable effects are likely to have been fixed in this population already [215]. QTL analysis started in the nineties and now a number of QTLs for many animal species are available **(Table 2)** followed by many sequences as described in **Table 3**, with a help of different molecular tools.

It was estimated that using markers linked to QTLs in goat, dairy and other livestock breeding programmes could increase animal response by up to 30% [234]. There are probable benefits from MAS and the scale of such potential benefits will depend on the QTL effect, the strength of the linkage between the marker and the QTL and the rates of possible changes by conventional means [235]. Utilization of modern molecular tools led to the discovery of thousands of QTLs associated with economic traits in livestock species including goats.

No.	Species	The size of genome (Gb) / (Mb)	Year	Refs.
1.	Mouse (*Mus musculus*)	2.6 Gb	2002	[216]
2.	Dog (*Canis Familiaris*)	2.4 Gb	2003	[217]
3.	Chicken (*Gallus Gallus*)	1.05 Gb	2004	[218]
4.	Cartilaginous fish] Elephant Shark[(*Callorhinchus milii*)	910 Mb	2007	[219]
5.	Monkeys]Rhesus macaque[(*Macaca mulatta*)	3.09 Gb	2007	[220]
6.	Platypus (*Ornithorhynchus anatinus*)	1.9 Gb	2007	[221]
7.	Cat (*Felis silvestris catus*)	2.7 Gb	2007	[222]
8.	Sheep (*Ovis Aries*)	2.78 Gb	2009	[223]
9.	Pig (*Sus Scrofa*)	2.2 Gb	2008	[224]
10.	Cattle (*Bos taurus*)	2.91 Gb	2009	[225]
11.	Horse (*Equus caballus*)	2.47 Gb	2009	[226]
12.	Amphibians] Western clawed frog [ )*Xenopus tropicalis*)	1.7 Gb	2010	[227]
13.	Panda] giant panda [(*Ailuropoda melanoleuca*(	2.4 Gb	2010	[228]
14.	Camel (*Camelus dromedaries*)	2.2 Gb	2011	[229]
15.	Tammar Wallaby (*Macropus eugenii*)	2.53 Gb	2011	[230]

No.	Species	The size of genome (Gb) / (Mb)	Year	Refs.
16.	Goat [Female Yunnan black goat] (*Capra hircus*)	2.66 Gb	2011/2012	[110] [231] [232]
17.	Goat [Black Bengal goat] (*Capra hircus*)	3.04 Gb	2019	
18.	Birds, [Mallard Duck (or wild duck)] (*Anas platyrhynchos*)	1.07 Gb	2013	[233]

Table 3.
The first sequenced genomes for many animal species.

3.7.5 Obtaining whole-genome sequencing (WGS)

The progress in sequencing technology has made new perspectives towards the magnitude of the genome analysis; sequencing time and costs have decreased dramatically and now WGS can be obtained easily [119] (**Table 3** and **Figures 5** and **6**). Obtaining the genome sequencing of goat and other domestic animals is extremely

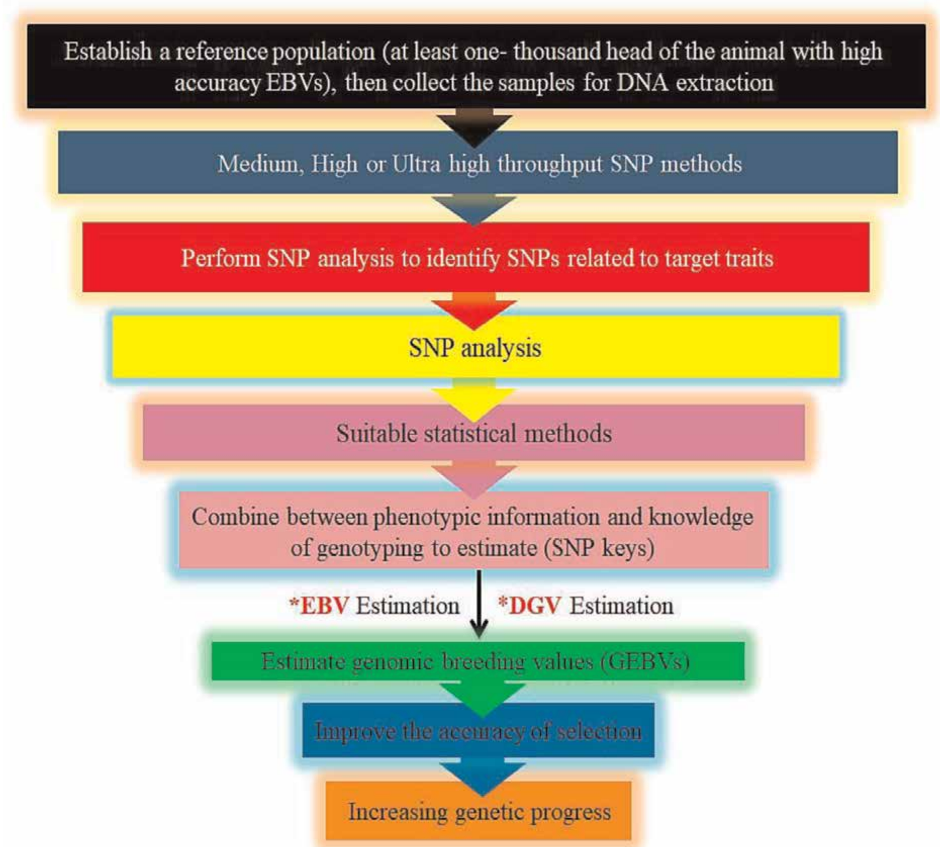

Figure 5.
The steps of implementing the genomic selection (GS). DGV: Direct Genomic Values and * EBV: Estimating Breeding Values (Developed by the authors).*

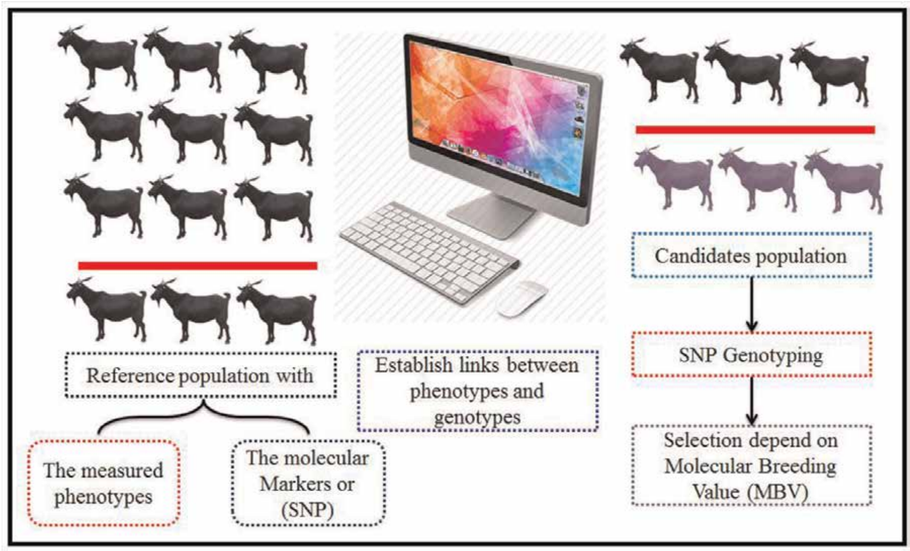

Figure 6.
The methodology of genomic selection in goat (Developed by the authors).

beneficial to detect the candidate genes, MAS, SS and QTLs, and their association with reproductive and production traits, animal health and welfare, also, is very beneficial to most animal production practices, besides understanding the genetic basis of the diseases, as well as GWAS applications [236–238].

More recently, several whole-genomes have been investigated for many livestock species with huge data about the history of these species and their domestication. Also, GWAS has been investigated in most of the economic traits in farm animals, for example, cattle [239], sheep [240], goat [241], pigs [242], chickens [243] and rabbits [244], but others still underway **(Table 4)**.

In a recent investigation by Fu et al. [132] based on the results of modern molecular techniques genomes of 24 bezoars,46 wild ibexes, 82 ancient goats and 208 modern domestic goats (~360 WGS) were used to produce a comprehensive genome variation database. That database hosts ~41,440,000 SNPs, ~5,140,000 *indels*, 6193 selected loci and 112 introgression regions which can be widely used in the future genetic comparison between different goat breeds worldwide.

Species	Year	*Refs.*
Dog (*Canis Familiaris*)	2003	[128]
Chicken (*Gallus Gallus*)	2004	[129, 218]
Sheep (*Ovis Aries*)	2008/2009	[223]
Cattle (*Bos taurus*)	2009	[225]
Horse (*Equus caballus*)	2009	[226]
Pig (*Sus Scrofa*)	2008/2009	[224]
Goat(*Capra hircus*)	2010/2011	[69]

Table 4.
Summary of genome projects for several animal species.

3.7.5.1 The Genome-Wide Studies (GWS)

An essential goal in animal breeding is to select individuals that possess effective BVs for target traits and allow them to be parents of the new generations. The success of GWS in finding variation sequences linked to important complex traits led to increased interest in SNP genotyping approaches in animal species, with the main goal of detecting QTL, candidate genes and then GS [245].

The appearance of SNP genotyping in combination with new advanced statistical methods to analyse the available data on the prediction of BVs had benefitted the extensive application related to WGS and genomic studies in livestock species. The scientific community had to implement GS in many animal species [92, 246].

3.7.5.2 Genome-Wide Association Studies (GWAS)

A GWAS is an approach that includes rapidly scanning genetic markers (GM) across the whole sets of genomes of several individuals to find the genetic differentiation associated with a specific trait [247]. Once new associations are discovered, investigators can utilize this knowledge to create and develop better strategies to improve the trait in animal populations [247, 248]. Also, identifying associations between genetic markers and important economic traits will provide practical benefits for the goat industry, enabling genomic prediction of BV of individuals and facilitating the discovery of the underlying candidate genes and mutations [75].

3.7.6 Signatures of selection (SS)

The high-throughput SNP genotyping/ NGS contributed significantly and strongly to uncover the signatures of selection (SS) in different livestock populations [249, 250]. Where the unique patterns of genetic left behind in the genome under NS or AS is defined as SS also, known as the change, elimination or reduction of genetic variation in the regions of genomic, neighbouring the causative variants in response to the pressure of NS or AS, it is also very important for GS [20, 251]. These signatures are often important regions of the genome that have unique sequence variants. This access is necessary and relevant because it has the potential to elucidate the identities of mutations and genes associated with traits related to phenotypes but with no need to measure them [251]. The availability of high-throughput SNPs and genomic tools able to increase exploring and identifying SS and other genomic diversity resulting from adaptation to selective pressure and environment [20] are successfully used in circumscribed datasets. The detection of SS helps to elucidate the effectiveness and identify mutations and genes associated with economic traits in livestock species. In addition, they are important to find out the levels of polymorphism and genetic diversity in a population, as genetic differentiation in animal breeding represents the raw materials crucial for the implementation of GS [252].

3.8 Genomic selection (GS)

Applying the information of wide-genetic markers in animal breeding was originally suggested by Meuwissen *et al*. [253]. The traditional principles of MAS were involved in a relatively limited number of genetic markers (GM) [254]. Those markers were recognized from research results of the primary analyses of controlled tests [255] **(Tables 3** and **4)**.

Nowadays, GS which is essentially a big-scale version of MAS involves a considerably big number of GM. The 'effects and roles' per each marker are simultaneously estimated during the process of GS. The number of MM involved in the genomic evaluations depends on the utilized procedure. GS assumes that all the trait's genetic differences must be explained through markers. However, the polygenic effects involved in the model to account for genetic variation might be un-explainable by GM [256]. GS should ultimately lead to utilizing genotypes defined by the polymorphisms to select target phenotypes [257].

GS may play a substantial role in improving traits which achieved genetic gains by traditional methods. Some important traits are expensive or difficult to measure such as carcass traits and resistance to diseases, and others are measured on one-sex or at the end of the animal life such as milk composition and production, and carcass characteristics, respectively. Available modern highly technical approaches such as GS can overcome the constraints in genetic improvement [25].

The GS has the ability to promote the resilience of animal species, especially small ruminants such as goats, for increasing production, adaptation and resistance to deadly diseases [258]. This includes breeding to resistance to diseases, parasites, fly strike and facial eczema [259]. Moreover, GS has ethical benefits in reducing the number of individuals susceptible to diseases and those who might be suffering in the coming generations. Investigations are now underway to allow the prediction of genomics for examination of farms important and effective biological traits such as methane emissions and feed efficiency. The examination of the last two traits involves high costs and cannot be widely disseminated on farms; thus, likely GS might a promising alternative [259].

GS depends on genotypic, phenotypic and pedigree data which might open a window for adopting breeding programmes in farm animals to improve meat, milk and fibre/cashmere production and the traits that are difficult to handle using traditional ways such as reproduction, breeding seasonality, longevity, meat quality and carcass composition [260]. The feasibility of GS to deal with small ruminants has been evaluated in French dairy goats [261, 262], Australian mutton breed [263] and French dairy sheep [264].

The methods of GS has been successfully applied in breeding programmes of dairy cattle and succeeded to reduce the generation interval. In goats, though the generation interval is shorter than in cattle and buffaloes, it still should be reduced. This increases the intensity of selection of the genetic gains per year and consequently reduces costs and increases productivity [25].

GS includes testing SNPs and their high-density effects utilizing a model fitted simultaneously to each SNP and treating these effects as random variables. Many Bayesian models have been updated to implement statistical estimation utilizing the methodology of the Monte Carlo Markov Chain (MCMC) [265, 266].

3.8.1 The methodology of genomic selection (GS)

To implement GS in any animal population source requirements should be fulfilled: 1) large number of goats per genotype, 2) availability of information on phenotype specific to each genotype, 3) statistical methods suitable for accurate and effective genetic prediction, assuming that the breeding programme is optimal, to achieve that: a) an accurate system of genetic evaluation to relevant phenotypes, b) the breeding objective should be related to target traits, c) the scheme of breeding ensures long-term sustainable genetic gain [267].

In general, 1) the obtained data will be used as a reference to develop the new statistical models for estimating the effects of SNPs on the target traits. 2) The results are predictive equation to estimate GEBV [268]. 3) In the absence of accurate phenotypes, the genomic breeding value (GBV) of new individuals can be computed from the prediction eq. (PE), depending on the genotypes from the SNP arrays. 4) The accuracy of GEBV depends on the heritability of traits of interest and the size of the population [117, 269] (**Figures 5** and **6**).

3.8.2 Advantages of Genomic selection (GS)

There are many advantages for GS: 1) provides an easy way to improve hard traits such as sex-limited, low heritable and those measured late in the animal life, 2) applied early in the animal life, 3) increases the accuracy of selection, 4) ability to be extended can be to the traits that are recorded in the reference population, 5) increases the genetic gain through reducing generation interval, 6) not limited to a specific population, 7) possesses high intensity and 8) explains the differentiation at the DNA level more than MAS [268].

4. Recent genetic and genomic studies on goats

In the last six decades, a lot of genetic attempts have been made to improve the goat production sector, starting in the 1960s until now (**Figure 7**). In recent years,

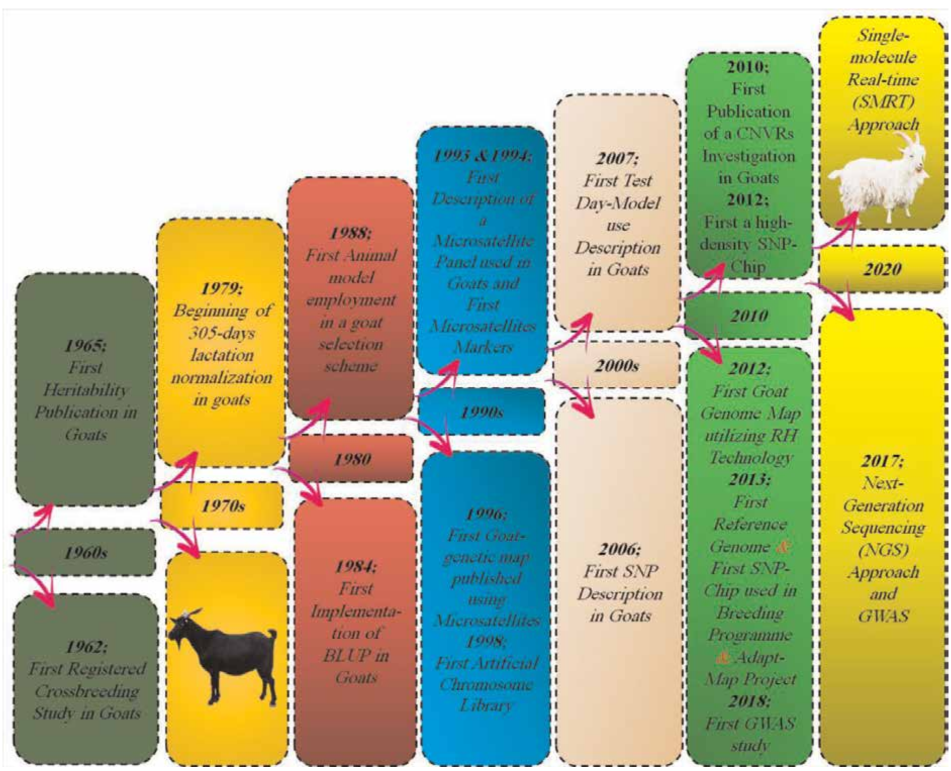

Figure 7.
Timeline of goat genetic improvement (Developed by the authors).

many studies have been analysing the genetics of goats, as one of the common domestic species adapted to extreme environments, and have phenotypic diversity. These studies have succeeded to identify the whole goat genome as well as some genes with key roles in domestication, adaptation to harsh environments or prominent economic traits [27, 110, 270].

Supakorn [106] and Saleh *et al*. [270] reported that more than 271 candidate genes have been identified and detected in goat breeds. This number will be doubled or tripled over the next few years with more focus on the association with economic traits [271, 272]. In addition, comprehensive studies have been done on the differentiation and polymorphism of several genes along with their roles in the control and management of economic traits. Moreover, some of these genes have either antagonistic or synergistic effects on the expression of phenotypic characteristics in nature. It is necessary to identify these candidate genes, along with their different impacts on economic and non-economic traits, which could help in goat breeding programmes. Also, it will be utilized as an aid in GS early in animal life [106, 272].

5. Conclusions

This chapter systematically introduces the basic information of the history, domestication and immigration of goats and modern versus old strategies to enhance goat genetic performance. It provides knowledge on the distribution of goats to the different regions of the world, the natural and artificial selection of goats, the production throughout the world, the vital role played by goats (fertility, milk, meat, fibres, land clearing, medical training, …) and the biodiversity of goat genetic resources, also, special characteristics of goats under different conditions. On the other hand, this chapter focused on modern strategies to enhance goat genetic performance, including different molecular tools, besides mentioning the outcomes of utilizing advanced molecular tools in goat breeding, as well as identification of candidate genes related to important economic traits, detection of SS and QTL, applied GWAS and the methodology of genomic selection.

In this chapter, the genetic investigations conducted on goats throughout the past three decades have been reviewed, along with a summary of the findings of those investigations in a focused manner with a discussion of the most significant QTL, candidate genomic regions and candidate genes that affect different body functions such as integrated course of adaptation, coat colour, skin sensitivity, body measurements, milk production, fibre production, meat production and quality, and goat diseases.

Thence, we believe this chapter is very crucial and will be a useful reference for readers and researchers to start answering the questions and solving the problems about goat production and industry. Also, we believe that this chapter opens a new window for researchers who are interested in the field of goat production development, especially genetic improvement, whether at the genome level or candidate genes. It also preserves the effort and time required to search dozens perhaps hundreds of investigations and studies related to this field which requires more investigations in the near future to cover every single gap in the previous studies.

Conflict of interest

The authors declare that they have no conflict of interest.

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Chapter 2

Crossbreed or Purebred, Which Is Better?

Suhendra Pakpahan and Ahmad Furqon

Abstract

The worldwide goat population has surpassed one billion individuals and there are more than 300 different goat varieties in the world, including purebred and crossbred. Presently, many studies on the characterization of local goats have been conducted to determine genetic diversity and find associations with specific traits, both for optimal performance improvement and adaptation to the environment. Purebred goats have very high adaptability to various environmental conditions, while crossbreds may not be as adaptable as purebreds. Farmers and associations were interested in increasing production and stabilizing performance by using better selection approaches. The selection for a standard appearance helped in the reinforcement of breed identity. The new commercial breed trend threatens to reduce the diversity of the global gene pool, whose diversity ensures goat survival in a changing future. Crossbreeding is most effective when the strengths and weaknesses of different breeds are identified and the appropriate role of a breed in a crossbreeding program is determined. Some exotic goats have been crossed with indigenous varieties in an attempt to increase milk and meat production, but the results have been mixed. The risk of genetic degradation in native pure breeds can be reduced while increasing performance and production through controlled crossbreeding.

Keywords: goat, purebred, crossbred, selection, grading up

1. Introduction

Domestication of goats began around 8000–7000 BC in the mountainous regions of West Asia. Domesticated goats (*Capra aegagrus* hircus) are descended from three groups of domesticated wild goats: bezoar goats (*C. aegagrus*) and the majority of goats raised in Asia are of the bezoar breed [1]. Local goats are used widely in countries all over the world. Presently, many studies on the characterization of local goats have been conducted in order to determine genetic diversity and find associations with specific traits, both for optimal performance improvement and adaptation to the environment [2–4]. Exploration of genetic diversity is particularly valuable for collecting information on genetic quality improvement and the conservation of local goats [5]. There is evidence that goats spread widely and contributed significantly to the development of Neolithic agricultural techniques wherever they went [6]. Nowadays, there are more than 300 different goat varieties in the world, including purebred and crossbred. The worldwide goat population has surpassed one billion individuals [7]. Goats have very high adaptability to various environmental conditions. According to several reports, goats can thrive in a wide range of environments, including human settlements, tropical rainforests, dry and hot deserts, and cold highlands. Therefore the history of each current breed must be determined, and genetic markers must be identified through DNA analysis [8].

Farmers were interested in increasing production and stabilizing performance by using better selection approaches. The selection for a standard appearance helped in the reinforcement of breed identity. On the one hand, such practices limit breed diversity. Breed identity, on the other hand, protects distinct genetic packages that would otherwise be lost in modern breeds. This new commercial breed trend threatens to reduce the diversity of the global gene pool, whose diversity ensures goat survival in a changing future. This is why we must secure our indigenous and heritage breeds. Goats are classified into three types based on their characteristics: meat goats, dairy goats, and hair goats. It's possible to classify dual-purpose goats as a fourth category, but there is no successful dual-purpose breed. Crossbreeding between native local goats and imported goats with differing appearances and performances has been carried out in Indonesia and numerous other Asian nations. Numerous studies over the past ten years have assessed breeds based on crossbreeding [9–11]. It is necessary to assess goat breeds with the potential for genetic enhancement of meat and meat products. The diversity of breeds and their husbandry techniques, diet, climatic conditions, natural vegetation, and terrain, labor surplus to household requirements, availability of trained personnel and equipment, social and cultural attributes, and economic reality must all be taken into account in order to develop breeding strategies that effectively exploit the biological ceiling of the species.

A new approach to livestock breeding called genomic selection has been successfully used for purebred population selection. Additionally, the genomic selection provides more chances to take into account data from crossbreds and choose for crossbreed performance. Even though the study utilized genomic data, it was less complex than the Wei and van der Werf model since there was only one breeding value for each animal and no phenotyping of purebred animals. A methodology for genetic assessment put out by Wei and van der Werf made use of data from both purebred and crossbred animals. Crossbreeding is most effective when the strengths and weaknesses of different breeds are identified and the appropriate role of a breed in a crossbreeding program is determined. In comparison to pure breeding, crossbreeding has two distinct advantages: heterosis and breed complementarity. The superiority of crossbred offspring over their purebred parents is known as heterosis. Another significant advantage of crossbreeding is breed complementarity. It refers to the fact that no breed is perfect, and that each breed has its own set of strengths and weaknesses [12, 13]. Breed resources are combined in a systematic crossbreeding program to balance the positive and negative aspects of each breed.

2. Materials and methods

This chapter gives an overview and summary of purebred and crossbred goats. This chapter was created using material collected from scientific publications such as journals, conferences, yearly progress reports from various international institutes and organizations, technical bulletins, statistics yearbooks, and others. This chapter contains general information about goat husbandry, tools and procedures, goat populations, and features of purebred and crossbred goats. The author's report in the publication is used to determine the accuracy of the information gathered.

3. Purebred dairy goats

The majority of the world's dairy goat production and consumption occurs in Asia, while Europe, particularly France, has the most organized market for goat milk [6]. In 2017, the worldwide dairy goat population was predicted to reach 218 million and total global goat milk production was estimated at 18.7 million tonnes [14]. Milk, meat, leather, manure, and other high-quality animal products may be produced from dairy goats, but dairy goat farming is designed to produce large amounts of milk. There are many different varieties of dairy goats found all across the world, the American Goat Society Inc. registers purebred dairy goats from nine recognized breeds of Alpine, LaMancha, Nigerian, Dwarf, Nubian, Oberhasli, Pygmy, Saanen, Sable, Toggenburg. Therefore, the specialist dairy goat breeds employed in high-income countries have a high genetic potential for milk production. Superior dairy goat breeds are more common in Europe and America because they have stronger development and selection programs than in Asia and Africa. These breeds have been transferred to many developing nations via live animal transport and sales of frozen semen or embryos (**Figure 1**).

The data clearly demonstrated that the gross chemical composition and physical properties of goat's milk were significantly influenced by animal breeds. Milk from graded goats was generally richer in chemical composition and had higher physical properties values than milk from pure breeds. Graded goat's milk has higher general average milk fat (4.28%), protein (4.31%), total solids (13.92%), ash (0.8%), titratable acidity (0.16%), specific gravity (1.0399), and viscosity (2.18 centipoise) [16].

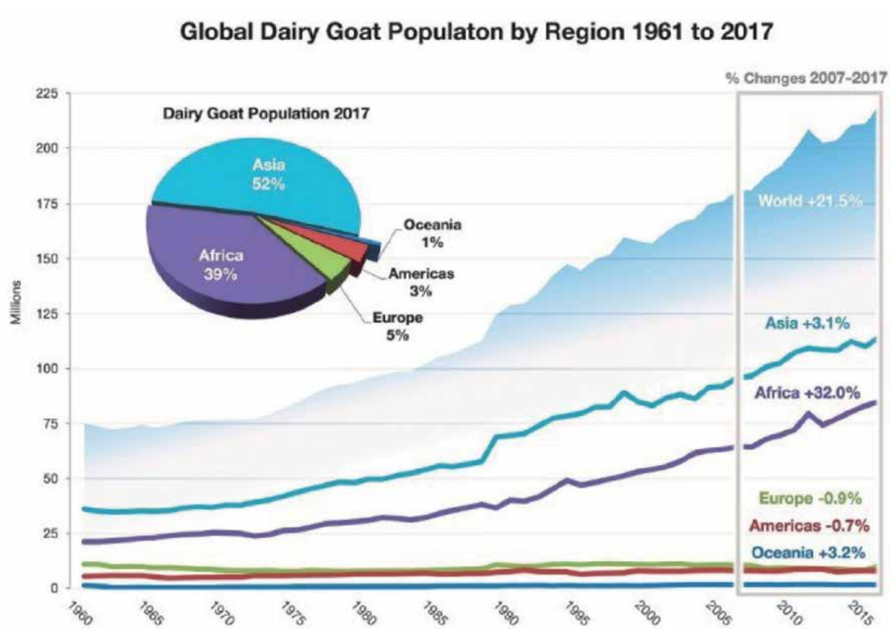

Figure 1.
World dairy goat population (heads) from 1961 to 2017 [15].

4. Purebred meat goats

The way to increase meat production is to increase the population and improve genetic quality. Key opportunities for increasing productivity include increasing reproductive efficiency through selection and crossing, increasing the genetic potential for growth, and improving nutrition and management practices to improve reproductive rates, child survival, and growth rates and composition. Improving daily nutrition and management offers opportunities to increase productivity [17]. Many types of meat goats are available for use in commercial operations. The popular meat goat breeds in the United States are described here. To be registered with their respective breed organizations, some breeds need to meet specific requirements, namely: Spanish or Brush, Boer, Kiko, Myotonic, Savanna, Pygmy or Cameroon Dwarf, and Nubian goat.

5. Performance of purebred

A purebred is the offspring of true breeding. True breeding is a technique for producing offspring with the same phenotype as the parents. When both parents are homozygous for certain traits, the result is a purebred. True breeding has the tendency to reduce the gene pool. A large gene pool indicates more genetic diversity.

Basically, genetics and environment influence performance. Moreover, reproductive system performance is controlled by both genetics and the environment. The massive development of molecular biology methods has opened up broad insights into genetic analysis [18]. Currently, there is a lot of genetic information related to the characteristics and diseases of goats. The search for genetic markers is very possible to find associations with certain traits. Based on data covering the reproductive performance from 2010 to 2012, including data from 23 multiparous does (11 does of pure Boer goats, 12 does of Boer x PE crossbred), the reproductive performance of pure Boer goats and crosses F1 and G2 (S/C, days open, kidding interval, and litter size) were compared and no significant difference was found [19] (**Figure 2**).

Reproductive performance is one of the most important drivers of production in goats, and it is determined by the combination of genetic and environmental variables. Peranakan Etawah goats are descended from crosses of Kacang (Indonesian native goat

Figure 2.
Indonesian local goats; A: Peranakan Etawah (PE) goat, B: Kacang goat [20].

breed) and Etawah (Jamnapari) goats. Reproductive data from 1.5-year observations of 480 dams; 200 Kacang and 280 Peranakan Etawah goats showed that the average litter size was 2.06 and 1.56; the birth weight was 3.8 and 5.4 kg; the survival rate to weaning was 97% and 92%; and the maximum calving interval was 205 and 450 days, respectively [21]. This comparison of reproductive performance data revealed that the Kacang goat (purebred) performs better in various segments except that the birth weight is lower than the Etawah Peranakan breed. The terminal crossbreeding of Murciano-Granadina goats with Boer bucks improved carcass and meat qualities [22].

The majority of goats reach puberty at a young age. Despite significant differences between genotypes, the sexes must be divided by or before 5 months of age. Yao and Eaton [23] discovered live sperm in the epididymis of dairy goats at 110 days. According to Rogers et al. [24] suggested that pygmy goats may reach sexual maturity as early as 3 months.

Earlier research on crossbreeding suggested that the majority of the advantages were due to heterosis observed in a single cross involving two divergent inbred populations originating from pure breeds. The heterosis of crossbred between Mexico's local breed and five goat breeds on estimated genetic parameters was various ranging from positive and negative values (**Table 1**). The heterosis in birth weight ranged from −1.04 to 1.69. The heterosis in monthly weight ranged from −1.05 to

Sire Genotype	**Heterosis**	**Standard Error**	**P (het ≠ 0)**
		Birth weight	
Nubia	0.30 (10.6%)	0.10	0.0025
Granadina	−1.04 (44.2%)	0.13	0.0001
Saanen	0.50 (17.1%)	0.12	0.0001
Toggenburg	0.44 (15.3%)	0.16	0.0006
Alpine	0.68 (23.1%)	0.09	0.0001
Overall	*1.69 (60.8%)*	*0.0001*	
Nubia	0.50(7.1%)	*Monthly weight* 0.27	0.0636
Granadina	−1.05 (1%)	0.33	0.0017
Saanen	0.80 (10.9%)	0.33	0.0142
Toggenburg	0.60 (8.4%)	0.45	0.1752
Alpine	0.15 (2%)	0.25	0.5552
Overall	*0.73 (10.2%)*	*Litter size*	*n.s.*
Nubia	0.82 (46.6%)	0.09	0.0001
Granadina	0.14 (8.2%)	0.12	0.2510
Saanen	−0.15 (9.7%)	0.11	0.1845
Toggenburg	0.24 (14.3%)	0.16	0.1448
Alpine	0.09 (5.8%)	0.09	0.3145

This data is from Meza-Herrera et al. [25].

Table 1.
Estimates of genetic parameters and heterosis for birth weight, one-month weight, and litter size at birth in five goat breeds.

0.8. The heterosis in litter size ranged from −0.15 to 0.82. the positive heterosis was found in Nubia Saanen, Toggenburg, and Alpine on birth weight and monthly weight. Otherwise, the negative heterosis occurred in Granadina on birth weight and monthly weight. Only Saanen has negative heterosis in litter size.

6. Performance of crossbred

In developing countries, the crossbreeding program is initiated in the 19th – 20th century by crossing between local and exotic breeds. The success of this program varies greatly and depends on the potential of local genetic resources and local conditions or environment [26]. The crossbreeding program is carried out to improve livestock performance and productivity. In addition, the crossbreeding program supports the socio-economic sector by increasing the income of farmers [27].

In general, the aims of the crossbreeding program are:

1. To benefit from the phenomenon of the heterosis effect

2. To get breeds effect and complementarity

3. To provide a base population of the established new breed

4. To improve performance and productivity

Crossbreeding programs could be classified into four different categories. The difference in these categories is based on heterosis use, use of adapted genes, conservation of local breeds, and genetic composition of the product. Those crossbreeding types are terminal crossing, rotational crossing, breed substitution/upgrading, and synthetic breed creation [28]. The success of the crossbreeding program is determined by several factors such as the determination of foundation breeds, the contribution of each breed, the mating system, and the recording system.

7. Effect of crossbreed on dairy production

In many countries, the crossbreeding program was performed to increase goat productivity in milk production and quality. Some dairy goat breeds with good milk production such as Alpine, Anglo-Nubian, Toggenburg, and Saaenen are commonly used to crossbreed with the local goat. Previous studies reported that the effect of the crossbreeding program successfully increased the milk production in F1 crossbred of the Alpine goat breed (♂) and Albanian goat breed (♀) [29]. Alpine goat is an imported dairy goat breed in Albania that has good milk yield and meat production. On the other hand, the Albanian goat is a local goat that has a good ability to deal with severe environmental conditions. The milk production of the crossbred showed shorter milking days and higher daily milk production compared to the local goat parents (**Table 2**). These improvements showed that there was the heterosis effect resulted in crossbreeding. It will be an important reason for crossbreeding.

In addition, a crossbreeding program was also performed between Saanen and the local dairy goat (Etawah grade) in Indonesia. The F1 crossbred is well-known as

Genotype	Heads no.	Milking day	Daily production (kg)		Total Production (kg)	
			Average ± SD	CV (%)	Average ± SD	CV (%)
Local breed	45	178.01 ± 2.1a	0.724 ± 0.03a	27.8	129.2 ± 4.9a	26.1
F1 Crossbred	58	171.86 ± 2.0b	0.967 ± 0.03b	23.4	167.1 ± 5.2b	24.2
Alpine breed	82	218.56 ± 4.1c	1.313 ± 0.04c	27.6	284.3 ± 9.7c	29.7

SD, standard deviation; Cv, coefficient of variation. a-c Values within columns with different superscripts are significantly different (P < 0.05) [29].

Table 2.
The least-square means of the performances of lactation in relation to genotypes.

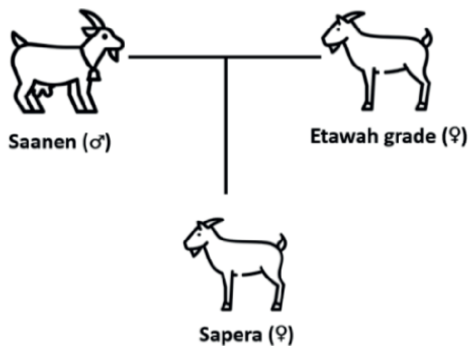

Figure 3.
Crossbreeding model between Saanen and Etawah grade [30].

the Sapera goat. The male Saanen goat was crossbred with the female Etawah grade to produce the Sapera goat (**Figure 3**). Suranindyah et al. [30] reported that the F1 crossbred has a higher milk production (1647 L/head/day) compared to the Etawah grade (1340 L/head/day).

8. Effect of crossbreed on meat production

Some goat breeds are raised for two purposes (dairy and meat goat) including the Saanen goat. This breed was widely used to crossbreed with the local goat to improve meat production and quality. In Turkey, the Saanen goat was crossbred with the indigenous Hair goat as Turkey's local goat. Yilmaz et al. [30] reported the effect of crossbreeding programs on carcass measurements and meat quality of kids under an intensive production system. There were 3 genotypes of goat used in this study i.e. indigenous Hair goat (purebred), F1 crossbred (Saanen x Hair goat), and B1 back-crossbred (Saanen x Hair goat).

The result showed that there were no significant effects of breed on carcass measurements (**Table 3**). It indicated that the crossbred was not superior to indigenous Hair goat kids in terms of carcass measurements and meat quality characteristics. On the other hand, F1 crossbred and B1 back-crossbred have better tenderness on the sensory characteristics of meat.

Characteristics	Hair		Saanen x Hair, F1		Saanen x Hair, B1		F
	Mean	SE	Mean	SE	Mean	SE	
----------Carcass Measurements----------							
Empty body weight (kg)	13.60	0.65	15.19	2.04	14.26	1.44	0.324[NS]
Hot carcass weight (kg)	6.78	0.39	7.61	1.17	7.02	0.80	0.280[NS]
Dressing percentage (%)	49.71	0.78	49.27	1.12	48.78	0.74	0.307[NS]
Carcass length (cm)	57.44	0.60	59.60	2.08	59.33	1.80	0.621[NS]
Leg length (cm)	18.24	0.26	18.89	0.62	18.56	0.42	0.544[NS]
Carcass width (cm)	16.19	0.52	16.86	0.80	16.33	0.52	0.323[NS]
Buttock width (cm)	12.96	0.16	13.04	0.74	13.50	0.98	0.186[NS]
Internal carcass length (cm)	51.36	0.69	54.04	1.20	52.85	1.32	1.579[NS]
Hind limb length (cm)	27.93	0.41	29.74	0.76	29.44	0.57	3.001[NS]
Thoracic depth (cm)	23.10	0.32	23.79	0.87	23.71	0.73	0.359[NS]
Carcass compactness (g/cm)	131.76	6.71	138.57	18.83	130.93	11.99	0.104[NS]
Hind limb compactness (g/cm)	37.09	1.77	40.13	5.53	35.56	3.77	0.364[NS]
Chest roundness index	0.70	0.02	0.71	0.01	0.69	0.01	0.701[NS]
-----------Sensory Characteristics----------							
Kid odor intensity	5.52	0.11	5.39	0.13	5.63	0.11	0.943[NS]
Tenderness	5.19[a]	0.15	4.71[b]	0.17	4.73[b]	0.15	3.107*
Juiceness	5.15	0.14	4.82	0.16	4.88	0.15	1.478[NS]
Flavor intensity	5.13	0.13	4.91	0.15	5.30	0.13	1.919[NS]
Flavor quality	5.29	0.12	5.14	0.14	5.30	0.12	0.470[NS]
Overall acceptability	5.21	0.12	5.11	0.14	4.98	0.13	0.867[NS]

NS, Not significant (P > 0.05), †SE, Standard error, a,b, Differences between the means of genotype groups carrying various letters in the same line are significant (= P < 0.05) [31].*

Table 3.
Carcass measurements and sensory characteristics of meat samples of hair and hair x Saanen crossbred (F1 and B1) kids.

9. Effect of crossbreeding on reproduction traits

Reproduction traits are one of the aspects affected by crossbreeding programs. The influence of crossbreeding was reported in Boer F1 crossed with base breeds in the United States [9]. The reproductive traits and survival rates were observed in the various genotypes (Boer, Kiko, Spanish, Boer x Kiko reciprocal F1 crosses, and Boer x Spanish reciprocal F1 crosses). In this study, Boer goats showed lower reproductive rates among the genotypes ($P < 0.05$). The survival rate of Boer was significantly lower than the Kiko goat ($P < 0.05$). All crossbreds had similar reproductive rates

Genotypes	Kidding rate (%)	Weaning rate (%)	Survival rate (%)
Boer	18.4 ± 12.7[b]	11.1 ± 9.7[b]	53.2 ± 11.8[b]
Kiko	81.7 ± 9.6[a]	67.1 ± 15.4[a]	84.8 ± 3.3[a]
Spanish	84.9 ± 8.3[a]	73.7 ± 13.5[a]	79.1 ± 3.8[ab]
Boer x Kiko	73.5 ± 12.4[a]	60.7 ± 13.5[a]	78.1 ± 3.9[ab]
Boer x Spanish	70.9 ± 13.2[a]	61.0 ± 16.6[a]	79.1 ± 4.1[ab]

[ab]*LS means (±SE) within a class and trait not sharing common superscript differ (P < 0.05) [9].*

Table 4.
Effect of doe breed and doe age on whole herd reproductive and survival rates.

compared to the parents (Kiko and Spanish goat). In this study, the crossbreeding program successfully improved the reproductive and survival rates (**Table 4**).

10. Conclusion

The selection for a standard appearance helped in the reinforcement of breed identity. On the one hand, such practices limit breed diversity. This new commercial breed trend threatens to reduce the diversity of the global gene pool, whose diversity ensures goat survival in a changing future. This is why we must secure our indigenous and heritage breeds. Crossbreeding can be done by combining the desirable characteristics of two or more breeds. If this program is carried out properly, the strength of one breed can complement the weakness of another breed through the phenomenon of the heterosis effect and breed complementarity. Controlled crossbreeding can increase performance and productivity and also reduce the threat of genetic erosion on native pure breeds. In developing countries, two-breed cross offspring developed from exotic breeds that have proven significant promise for greater production in their country of origin, and local goats (native) with superior adaptation are thought to be more productive under local conditions. This misconception has encouraged generations of unintentional crossbreeding, frequently leading to an upgrade to exotic breeds and resulting in the loss of vital traits like adaptability, fecundity, and disease resistance as well as a narrowing of the genetic base that negatively affects the performance of the crossbred population. In order to crossbreed animals from particular breeds, it is necessary to assess the likely sources of breeding animals in each country.

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Conflict of interest

There is no conflict of interest.

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Section 2

Genetics

Chapter 3

Current Status of Molecular Genetics Research of Goat Breeding

Ayhan Ceyhan and Mubeen Ul Hassan

Abstract

The goat is an important part of livestock farming due to their meat, milk, wool, and other products. The understanding of the goat genome has opened drastic opportunities for productivity improvement. Many important genomic technologies have been developed, including microsatellites, single nucleotide polymorphism, and whole genome sequencing, and these techniques are being used to identify important genomic regions in the goat genome. Identification of important genes related to meat, milk, and wool can help design breeding programs for increasing the productivity of goat farming. Recent advances in genome engineering tools like zinc finger nuclease, TALENS, and CRISPR/Cas9 have also made it easier to engineer farm animal genomes. Medically and commercially important genes are being engineered in farm animals for medicinal and commercial purposes. This chapter will focus on some of these technologies being applied in goat breeding to increase animal health and the commercial economy.

Keywords: *Capra hircus*, genetics, microsatellites, SNP, GWAS, genome engineering, productivity

1. Introduction

Goats (*Capra hircus)* being an important livestock animal have helped to reduce poverty and increase the life standard of small farmers in rural areas [1]. The continent of Asia and Africa has been hosted more than 90% of goat farming [1]. Goats are considered to be the 1st animal domesticated by humans and are the part of "big five" livestock animals along with cattle sheep, chickens, and pigs recognized by FAO. The domestication of goats started 10,000 years ago with four different domestication events reported involving the Bezoar being the first wild ancestors in Southwest Asia [2]. After domestication events, humans were accompanied by goats during their migration all around the world. About 5000 YBP during this migration period the goats arrived at the edge of the west and far north edges of the European continent [3]. At the same time, the expansion continued eastwards into Asia and southwards into Africa. The presence of goats in Ethiopia and the Sahara is reported around 5000 YBP [4, 5], however, the presence is reported a little later in north Africa at about 6000–7000 YBP [6]. The expansion of goats and sheep was slowed down due to the occurrence of trypanosomiasis in Saharan Africa, even though both of these animals arriving sub-Saharan Africa only 2000 YBP. The evidence of goats' presence in Asia suggests their occurrence was reported in China around 4500 YBP [7], and during the subsequent millennia, they moved further east. The hypothesis of Asian cashmere goat breeds [8, 9] origin in Asia due to domestication events is reported, however, the recent molecular evidence of the Cashmere goat breed's origin denies these hypotheses [2]. The migration of the European population toward the Americas and Oceania carried along goats to these continents in the fifteenth and eighteenth centuries [9]. This suggests that goats have been dominant livestock for humans in different agroecological and geographical areas of the world.

The past 100 years have seen technological modification and new scientific methods, which have caused an immense increase in the outcome of livestock globally. The selective breeding programs in livestock animals to produce animals better suited to the environment, management systems, and better productivity drove the manipulation of animal genetic resources. These modifications directed at increasing the genetic potential of livestock resulted in new breeds for major livestock animals, which contributed to increasing the income of farmers. Initially, inventions in reproduction techniques made it possible to deliver high-merit genetics for breeding programs resulting in increased selection pressure. In addition, improvements in computing methods, selection accuracy, and breeding value estimation were observed affecting the animal selection programs, the combination of these approaches with quantitative and qualitative genetics resulted in the development of genomic tools, which resulted in increasing the production potential of farm animals by many folds over time. Therefore, these developments caused a drastic change in approaches directed toward improving livestock productivity. For instance, during the period of 1957–2005, an increase of 400% in broiler growth rate and an increase of 50% in food conversion rate has been recorded [10]. These approaches and tools have not only resulted in accelerating the progress rate in the livestock industry but also have been a major reason for understanding the lifespan of animals and complex biological pathways controlling the productivity-related traits in farm animals. In addition, the breeding programs focused on increasing the production and yield of livestock not only achieved productivity but also the lifespan of these animals under selection saw improvement [11]. Over time these breeding programs have expanded their goals targeting multiple characteristics in animal health, welfare, survival, fertility, and other welfare-affecting characteristics in animals (**Figure 1**) [12–14].

All of these notable and important characteristics affecting the commercial value of livestock are defined by the genomic makeup of animals. The vast majority of the genes in sheep and goat genomes affecting productivity traits have been identified. These genes are controlling important characteristics like disease resistance, sensitivity, production performance, and reproductive performance. Their identification has resulted in controlling the targets for improving economic traits through genetic variation [32, 33]. The discovery coupled with molecular genetics techniques has provided the possibility of increasing the selection accuracy in the early stages of the breeding programs [34]. In addition, molecular genetics has provided information on individual candidate genes related to individual economic traits. These individual candidate genes targeting approaches help to identify important qualitative traits loci (QTLs) in the genes [35, 36].

A number of studies have reported the candidate genes influencing milk, wool, reproductive, disease resistance, and growth traits in goats [37]. However, there are also genes that control more than one characteristic in goats, for example, the GH gene (growth hormone) is influencing both milk and growth traits. The candidate genes are involved in sex determination, disease resistance, reproduction,

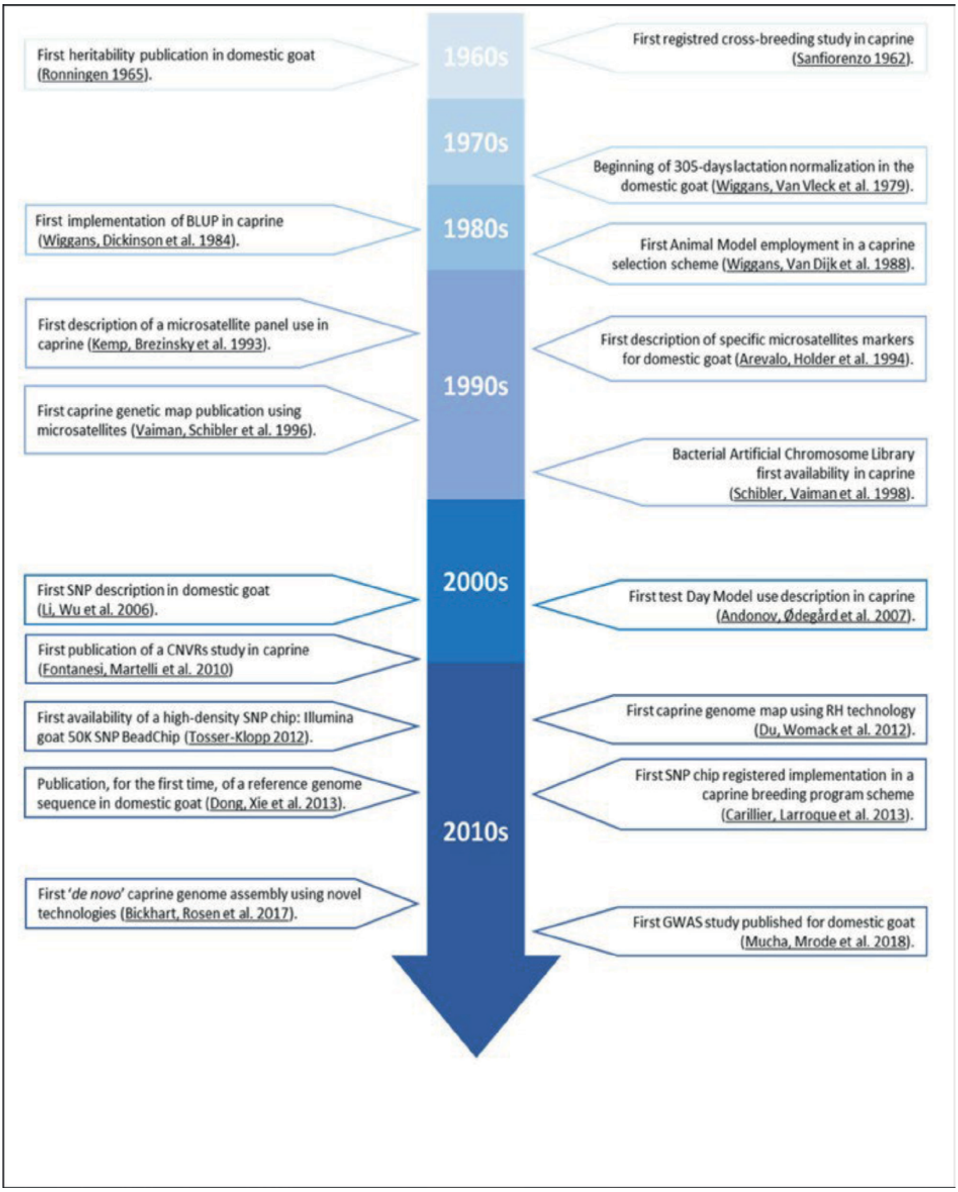

Figure 1.
Chronology and timeline of caprine genetic advances milestones [15–31].

metabolism, and productivity in goats proving to be economically important [38–44]. The techniques involved in the candidate gene studies have the ability to identify the region of genes where genetic variation at QTL is present and how it is affecting the trait [45]. Molecular genetics provides us with the ability to identify this genetic variation at specific loci and manipulates them to increase goat productivity.

In this chapter, our aim is to discuss the technologies involved in underlining the importance of genetics in increasing the productivity of goat productivity. In addition, we will also focus on the areas of genetics that provide a great service to better the production and productivity of goats.

2. Use of genomic tools

The genomics approaches started in the 1980s, and the major focus for developing this technology was to develop standalone genomic markers that can be used against inherited diseases and for parentage testing [46, 47]. Thereafter, the focus shifted from parentage testing and inherited disease toward the more economical traits affecting QTLs to be used in marker-assisted breeding, through combining quantitative genomic technologies and marker-assisted selection (MAS). Furthermore, the fact was then realized that these commercially important traits are not controlled by the expression of a small number of genes instead, it is controlled by hundreds of genes involved in the expression of these economic traits, this made way for a further intensive approach for development. The recent 15 years saw the refining and implementation of different methods to be used in genomic selection. The advances in the genomic selection methods combined with data analytic techniques and computing methods have helped to generate a large amount of information for predicting breeding value efficiently.

2.1 Microsatellites methodology and application

Short tandem repeats also known as microsatellites are simple sequence repeats, which are present in the genome of all mammals. These are identified by designing specific primers according to specific sequence repeats for DNA flanking microsatellite regions and are amplified through a polymerase chain reaction. The microsatellites unit number may vary depending on the microsatellites and the number of repeats can change from 2 to 30.

The methodology of microsatellites is related to designing specific PCR primers that are related to specific specie and their specific place in the genome, two primers are designed for microsatellites on either side of repeats. After applying the primers, the segments are amplified in the PCR, the PCR amplified segments are then analyzed either on capillary electrophoresis or gel electrophoresis. However, the investigator can determine the times' the CA dinucleotide was repeated and its size for the individual allele. Furthermore, it is more desirable to get two bands on the data but sometimes the data also shows minor bands in addition to two major bands, this difference is mostly of two nucleotides from the major bands, and these are called stutter bands [48].

Using PCR primers in research of two multiplex systems consisting of 11 microsatellites associated with parentage testing in goats was characterized [48]. Of these microsatellites, 18 were found to be located on 16 different chromosomes, and these were identified in different animals: five from sheep, nine from cattle, and eight from goats. The parentage exclusion probability was calculated to be higher than 0.99999 and two identical genotypes found probability of less than 10–15. This shows the reliability of microsatellites for parentage testing. The effective number of PCR primers is discussed periodically and currently, the accepted number is 14 [49]. In addition to parentage testing, pedigree verification is also another thing where microsatellites have been a handful [50]. The Murciano-Granadina goat nucleus herd pedigree verification study in Spain of 388 animals resulted in 16.2% (63) being incompatible and 71.9% (279) compatible. The incompatible animals were considered due to data transfer errors, or the archaic system used. These results suggest using the microsatellites for reducing the errors in the breeding programs of goats. A 10% parentage misidentification can lead up to a reduction of 4% in genetic progress

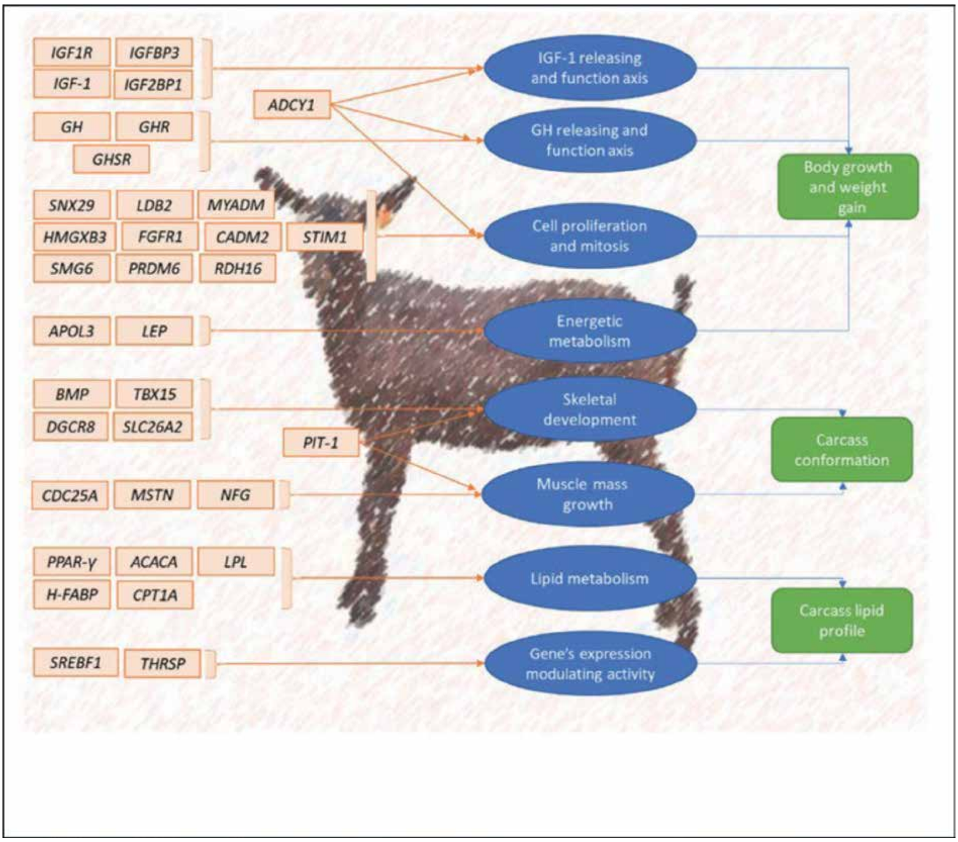

Figure 2.
Figure showing the important candidate genes for meat production in goat genome [54].

[50]. Microsatellites can be a good assistance for the genetic conservation of animal resources, particularly for endangered species, and are being used as a tool for these experiments (**Figure 2**) [51–53].

2.2 SNP chip methodology and application

The techniques that followed microsatellites in genome exploring are single nucleotide polymorphisms also known as SNPs. An SNP is a difference of one nucleotide on specific loci on a chromosome. This can happen after a nucleotide is replaced by another at the original place for example thymine (t) being replaced by cytosine (c). The SNPs are present in the genome of all living species, including goats.

The several research projects conducted according to International Goat Genome Consortium (IGGC) guidance, the goat genome was sequenced successfully helping to identify 12 million high-quality variants of SNPs in the genome [55]. This resulted in the creation of an SNP database which contains the technical and biological characteristics information from IGGC (International Goat Genome Consortium) by using advanced SNP detection and bioinformatic tools. The important feature of the SNP database created by IGGC included the selection of minor allele frequencies for diverse breeds, the technological success rate of SNP design, and evenly spaced SNPs in the genome.

The methodology of detecting SNP using the chip is a high throughput, most automated procedure [56]. These are designed on the DNA microarray principle, which contains specific probes depending on the target genome. These SNP probes are hybridized into a DNA sample to check the target allele for SNP. However, the data collected from these arrays are not as complicated as WGS for analysis, requiring bioinformatical software for data processing and analysis. In addition, these SNP arrays can only detect those SNP whose locus on the genome is already characterized, requiring prior genetic information.

The SNPs identified between and within six breeds, Savanna, Alpine, Boer, Saanen, Creole, and Katjang goats, could also be used for the breeds not included in the experiment [57]. The validation for these SNP was conducted by using 52,295 SNPs in the ten goats and was successfully genotyped, which led to a 52 k SNP chip (Illumina, Sandiego, California, USA). These 52 K SNP chip developments created acceleration for advanced goat genome studies. Thus, the turning point came with the evaluation of the economic production trait of goats [24, 58]. A genome-wide association study (GWAS) of the goat genome for important economic traits in the UK followed shortly after the manufacturing of 52 k SNP chip [48]. The GWAS combines phenotypic data like the meat yield of goats with the information collected from the SNP chip [59]. The study carried out in the UK focused on the udder conformation and milk yield traits.

2.3 Use of whole-genome resequencing and methodology

The new developments in next-generation sequencing methods and their reduced cost have gained increased interest in whole-genome genome resequencing as compared to its alternative of genotyping by using SNP chips in breeding programs. Resequencing of whole genome offers a large number of specific variations in the target population as compared to its rival SNP genotyping, which is based on common SNP selected from different populations. Initially, the use of low-cost genotyping by sequencing was tempered after the discovery of the quality of variations obtained from genotyping by sequencing was lower as compared to the quality of variations obtained from genotyping by SNPs due to the lower depth of genome coverage. However, when the genotyping quality was increased with increased genome depth the cost also went up [53]. The characterization of common variants is also available on SNP chips; the use of whole genome sequencing provides advantages that include the characterization of copy number variations, structural variations, and other rare variants.

The basic procedure for next-generation-based whole genome resequencing includes these principal steps, DNA extraction, target enrichment, sequencing, and library preparation. The data obtained from these steps after the sequence is raw data and it further undergoes quality control, demultiplexing, variant identification, mapping for reading the reference genome, and annotation. The above-explained procedure leads to the generation of a variant call file, and after the consistent exhibition of differences in multiple reads, the SNP is called [60].

In goats, comprehensive studies have been carried out to underline the polymorphisms in economically important genes. These candidate genes control the metabolism, physiological pathways, and expression of phenotypes. The important genes are sex determination and proliferation are the SRY gene of the Y chromosome, amelogenin (AMEL), the reproduction-controlling gene FOXL2, and the melatonin receptor gene MTNR1A. The genes bone formation BMP (bone morphogenetic protein), POU1F1 gene for caprine pituitary specific transcription, LEP (leptin), MSTN caprine myostatin, IGF insulin-like growth factor, GH growth hormone, and GHR growth hormone receptor are responsible for body weight muscle growth, body condition, birth weight, body condition, bone formation, and weaning weight. The genes like MC1R melanocortin 1 receptor and KAP keratin-associated proteins are involved in wool production traits. The casein gene family is the major gene that is involved in milk production in goats. The important gene family involved in the immune system response is MHC major histocompatibility complex. The normal function and expression of all these genes are keys to better production in goat farming [37].

The important gene for milk-related traits and milk yield is casein gene family. The genes involved in wool production are melanocortin1 receptor and keratin-associated protein. Major histocompatibility gene family is known to be involved in developing the immune system of animals against the disease and disease resistance [37].

The major candidate genes for milk yield and milk composition traits are the casein gene and their family. Keratin-associated protein (KAP) and melanocortin 1 receptor (MC1R) genes are candidate genes for wool traits. The major histocompatibility complex (MHC) gene is considered important for the immune system and disease-resistance traits. The functions of these genes on economically important traits are different (**Figure 3**) [37].

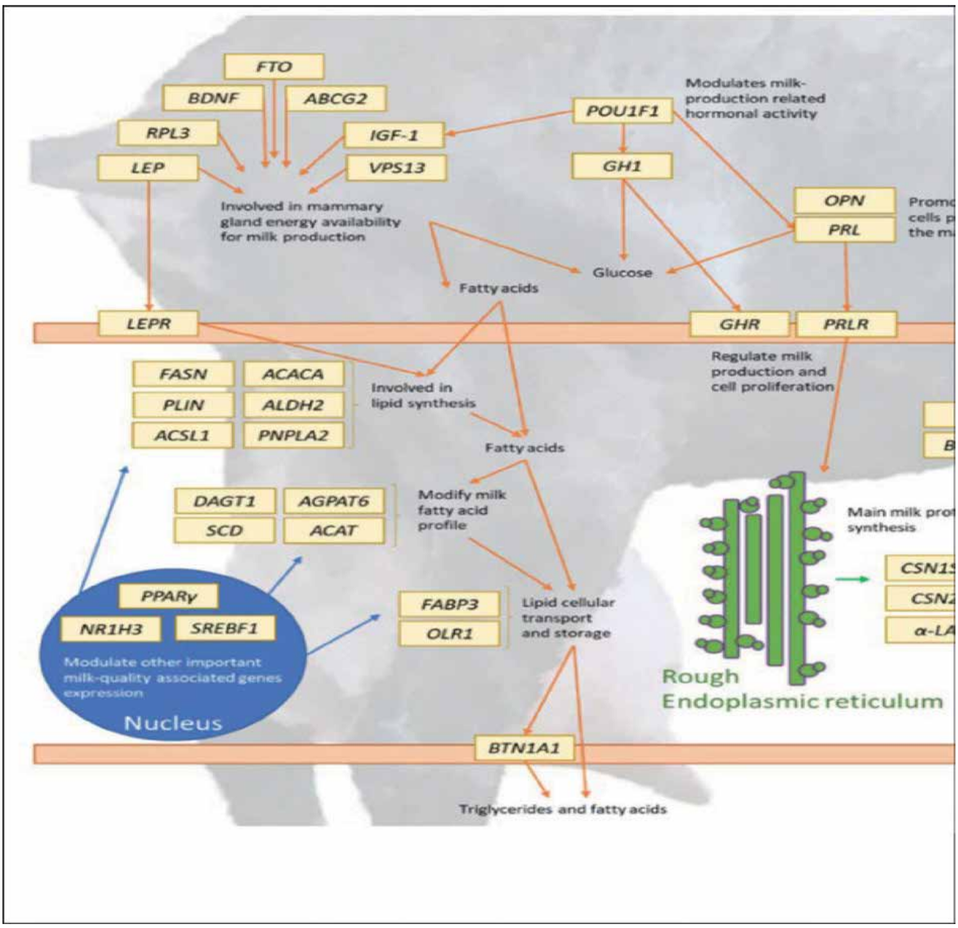

Figure 3.
Schematic diagram showing the milk-related different genes and their relation to each other [54].

2.4 Genome engineering by the applications of CRISPR/Cas9 in goats

Genome engineering has been revolutionized due to modern tools, which make it possible to engineer genomes more precisely and efficiently with desired results as compared to conventional genome modification tools. One of these advanced genome engineering tools is CRISPR/cas9, which has been applied to goat and sheep genomes to fulfill the desired targets. Until today, numerous models for sheep and goats have been engineered through CRISPR/cas9 systems. Further studies are continuing to provide useful models of sheep and goats for the service of biomedicine and agricultur (**Figure 4**).

Accelerating the growth rate and enhancing the body weight of livestock animals have been the key goals of farm agriculture. The genes that are responsible for these economic traits are the key targets for advanced genome engineering technologies.

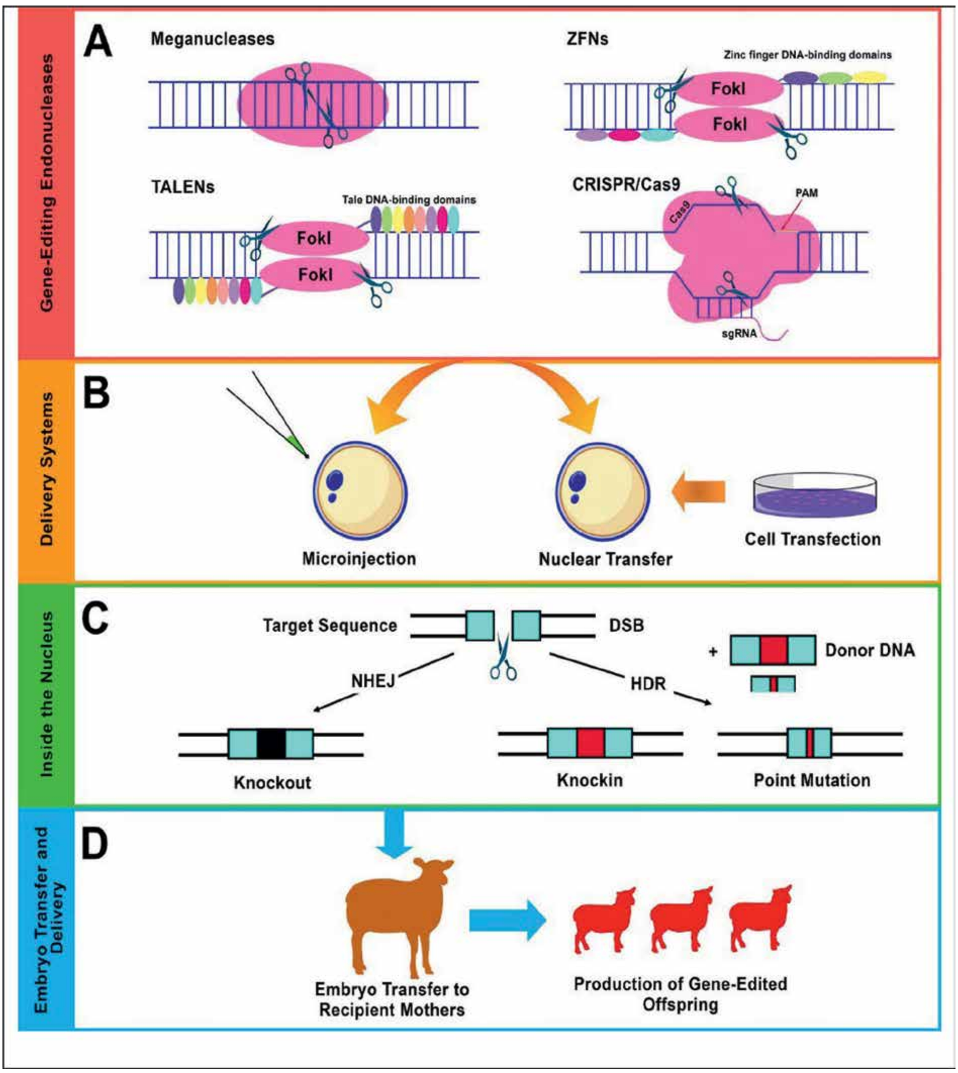

Figure 4.
The visualization of procedure involving TALENS, ZFNs, and CRISPR/cas9a [61].

The first gene to be targeted by CRISPR/Cas9 is MSTN, in accordance to achieve the goal of engineering the most important gene modification in goats and sheep.

Furthermore, the steps are being checked in order to make it safe for engineering the genome in big animals, for this, a trio-based sequencing has been carried out to investigate the variations discovered in edited samples, which could have been naturally obtained, parentally inherited or a result from specific target occurrence [60]. The results of the experiment showed a negligible amount of off-target editing, which does not affect the use of CRISPR/Cas9 in large livestock. These results provide information about the potential of multiplex editing by CRISPR/Cas9 in large animals.

The methodology of the CRISPR/Cas9 system of gene editing involves creating a double-strand break in the DNA by the Cas9 protein. The target gene that needs to be disrupted is cut by DSB. The cleaved DNA segment can be repaired by two pathways NHEJ (non-homologous end joining) and HDR (homology-directed repair). Nonhomologous end joining is used to create knockouts for the genes by deleting some nucleotides from the DNA sequence of the gene. However, the homology-directed repair will lead to the insertion of predicted DNA segments. The DSBs created in the DNA sequence of a gene make it possible to delete one or more nucleotides and also can be used to insert a few nucleotides or a segment of DNA in the genome of the target animal at the specific target site [62].

CRISPR/Cas9 was used to edit 4 important genes in goats PrP, MSTN, nucleoporin 155 (NUP155), and BLG, in goat fibroblast, and three knouts for MSTN in goats were generated by using SCNT [63]. The end results of the study showed an efficiency ranging from 9 to 70% by using CRISPR/Cas9, which indicates the potential of this technology to be used in the caprine system. Later than this further knouts for fibroblast growth factor and MSTN in goats or for both have been reported [64]. From the total of 98 individual animals obtained, only 14 lambs died shortly after birth while 79 lambs were alive and five lambs were aborted. Furthermore, 10.2 % (10/98) showed disruption in both genes, 21.4% (21/98) showed disruption in FGF5, and 15.3% (15/98) showed disruption in MSTN. These results approve the ability about the efficacy and efficiency of CRISPR/Cas multiplex targeting in large farm animals. Specifically, because the economic traits are controlled by multiple genes in different locations. Further investigations were also conducted on these founders' edited mutants from the above study to check the viability and authenticity of knockout alleles transmission and gene disruption [65]. In addition, the MSTN-disrupted goats were also analyzed for transcriptomic changes [66]. The transmission and occurrence of the disrupted genes were confirmed, and also considerable changes at the transcriptome level and gene expression level were also confirmed. The changes at the expression level were recorded in the unsaturated fatty acid biosynthesis and fatty acid metabolism, which suggests that MSTN plays and regulatory role in the expression of these genes. Moreover, the researchers also conducted trio-based family sequencing of the engineered progenies and goats to look for any indels, structural variants, and other *de novo* mutations [67].

The occurrence of FGF5 knockout simultaneously at genetic and morphological levels has been confirmed and an increased secondary hair follicle number and high fiber length were also seen [68]. Another study was conducted to check the disruption effect and hair follicle development and growth phenotype by creating a goat knockout through SCNT, CRISPR/Cas9 was used to disrupt the EDAR ectodysplasin receptor gene. The knockout EDAR genes generated showed the absence of top hairs on heads and primary abnormal hair follicles, these are the specific features of EDAR knockouts. These founders of EDAR knouts generated by CRISPR/Cas9 provide a model to study the relationship between hair follicle growth and development with the EDAR gene.

The study of hair follicle growth and development genes is of primary importance because they are the key features of cashmere and wool-producing goat breeds. FGF5 gene engineering using CRISPR/Cas was carried out by introducing nonsense codon introgression in the gene to increase the production of cashmere hair goats [69].

The functional role of some genes like acetyl CoA acyltransferase 2 ACAA2 in sheep adipocyte cells and in the mammary epithelial cells of goat gene stearoyl-CoA desaturase 1 has also been investigated by using CRISPR/Cas9 [70, 71]. These genes are known to affect directly or indirectly related to fatty acid metabolism and milk traits. CRISPR/Cas9 has also been used to produce sheep and goats with modified milk production characteristics that can be very important for the large-scale production of important pharmaceuticals and proteins in their milk.

In another study, a defined point mutation was introduced in the goat genome by using CRISPR/Cas9 in the GDF9 growth differentiation factor 9, which is largely related to litter size and ovulation rate [72]. The study showed a targeting efficiency of 22.2% with 4 kids carrying the mutation out of 18 injected. In short, both of the above studies showed very successful cases of inducing a reliable and specific point mutation in livestock by using CRISPR/Cas9-induced HDR. In another investigation, they checked the effect and efficiency of open-pulled straw vitrification as a technique for preserving microinjected embryos over the reproductive capacity of AANAT transgenic offspring and AANAT microinjected embryo development [73].

Furthermore, CRISPR/Cas9 technology has been used to target fibroblast PrP gene and generate PrP gene knockout donor cells, which will then be applied with SCNT to produce goats with PrP resistance [60, 74, 75]. The target efficiency was recorded at 20% when both of the genes MSTN and PrP were targeted simultaneously, and this target efficiency was increased to 70% when only a single PrP was targeted. Thus, the results of these experiments suggest CRISPR/Cas9 technology can be highly used to produce disease resistance in domestic and commercial livestock.

3. Conclusion

The recent past has seen numerous technological advancements in the goat genetics and breeding field. These technologies have been successful in helping goat breeders to increase the productivity of goats. Goat genome studies have been the key focus of most scientists, which helped the technologies to research through genomic regions and exploit them for increasing the meat, milk, and wool production in the goat. Genome modification tools have become necessary in recent years for research in agriculture, biomedicine, and model studies. Genome engineering tool such as CRISPR/Cas9 provides an immense number of opportunities for revolutionizing farm and agriculture research. Therefore, applying these research tools to goats will create significant results. The use of CRISPR/Cas9 to generate genetically modified animals like goats, sheep, and cattle is currently going on in the world and the list will keep on growing.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 4

Finger Printing of Three Indigenous Goat (*Capra aegagrus Hircus*) Breeds in Nigeria Using ISSR Marker

Hannah Etta

Abstract

DNA Finger Printing of three goat breeds Red Sokoto (RS), West African Dwarf (WAD) and Sahel White (SW) in Nigeria was carried out. Standard procedures for blood sample collection, DNA extraction and analyses were employed. Analyses carried out included PCR amplification, band scoring, Population Differentiation investigations and percentage variability studies. Results obtained revealed 58.33%, 100% and 50% amplifications of the RS, WAD and SW breeds respectively; band scoring revealed polymorphism across the goat breeds; population differentiation showed four population structures and percentage variability studies gave 100% variability within the goat breeds and 0% among breeds. These results indicate high genetic variability of the three goat breeds and presents the ISSR primer as an appropriate tool for diversity studies of these breeds.

Keywords: DNA fingerprinting, red Sokoto, west African dwarf, Sahel white, genetic variability

1. Introduction

Goats (*Capra aegagus hircus*) like other livestock species, play a significant role in sustainable agriculture Goats constitute the largest group of small ruminant livestock in Nigeria totaling about 53.8 million. Goat in Nigeria constitutes 6.25% of the world's goat population. Traditionally reared stock contributes about 99.97%, while 0.03% of the stock is commercially managed [1].

The Nigerian indigenous goat breeds possess adaptive features that enable them to thrive in their different environments (**Figure 1**) [2]. Some of these adaptive features include small body size and generation interval [3], ability to thrive in hard conditions and ability to survive on poor quality diets provided by scarce grazing on marginal lands [4]. The adaptability of these breeds in different zones give variation of germplasm [5].

The adaptability and survival of a specie is affected to a great extent by genetic diversity [6]. As changes occur in the habitat of a population, there is need to adapt if the population must survive. How the population successfully copes with challenges

Figure 1.
Goat breeds involved in the study. (L-R) west African dwarf goat; white Sahel and Sokoto red. Source: [2].

in the ever changing environment depends on how easily the population was able to adapt to the changes [7].

DNA fingerprinting also known as genetic fingerprinting, DNA typing or DNA profiling is a molecular genetic method that enables identification of individuals using hair, blood, semen or other biological samples, based on unique patterns (polymorphism) in their DNA [8]. Several methods of DNA finger printing exist either using RFLP or PCR or both. These methods mostly target different areas of DNA especially those with known variation in single nucleotide polymorphism; (SNPs), short tandem repeats (STRs) and other variations that repeat polymorphic regions. Repeating sequences and their sizes, in our genetic make-up makes it easy to identify an individual correctly [8]. Inter-simple sequence Repeats (ISSR) are molecular markers which have been proven to be valuable tools in the characterization and evaluation of genetic diversity within and between spaces and populations [9].

Inter Simple Sequence Repeat (ISSR) technique is a PCR base technique, reported by [10] which involves amplification of DNA segments between two identical microsatellite repeat regions oriented in opposite direction using primers designed from microsatellite core regions. ISSR primers generate polymorphism whenever one genome misses the sequence repeat or has a deletion or insertion or translocation that modifies the distance between the repeats.

This investigation was designed to carry out DNA fingerprinting of the local goat breeds in Cross River State of Nigeria as there's no such records yet. It is hoped that inferences from the investigation will provide baseline information for conservation and future breeding practices by goat breeders in Cross River State and Nigeria as a whole.

Three main varieties of goats are recognized in Nigeria - the Sahel, Desert or West African long-legged goat, the Sokoto Red and the West African Dwarf. These are the species we investigated.

The Sahelian goat is found along the northern border of Nigeria particularly in Borno, where it is often known as Balami, although this name has not been adopted as it would lead to confusion with the better known sheep race, Balami [11]. In Nigeria the Sahel goat is generally the variety preferred by pastoralists. Sahel goats are very similar in appearance to the sheep with which they are often herded. The coat is white or dappled, the ears are pendulous and the legs are notably longer than other breeds [12].

The sokoto red, Kano brown or Maradi goat is probably the most widespread and well known type in Nigeria [13]. It is the usual village goat in the North. The Sokoto red is the only Nigeria breed for which there is a record of systematic attempts to stabilize. The Sokoto red is still known for its suitability for fine leather. The skins have coarse thinly-spaced outer hairs and small sweat and wax glands and they lack fat.

Although the West African dwarf goat is found in many local types [14] there's no record that they are actually different. The WAD are believed to be originally from the forest belt but they have been identified in Borno state, Cameroun and Chad showing a wider distribution of the breed. [15] described the breed as Grassland dwarf in Cameroun. Indeed, like Muturu cattle, they may once have been the main race of goat over most of Nigeria. Just as the Zebu has replaced the Muturu, so WAD goats have been driven to remote areas in the savannas. The West African goat is usually black, although patched and occasionally all white animals can be seen, even on the coast. Paradoxically, physiological experiments have shown that the WAD goat is not practically adapted to high ambient temperature [16].

2. Materials and methods

Blood samples were collected into EDTA vacutainers and stored in ice until commencement of molecular analyses. The CTAB method was used for DNA extraction. The DNA was quantified, assessed and then diluted to 100 mg/μL DNA prior to polymerase chain reaction (PCR) set up. As it was detailed in [17], 25 μL volume of 2.0 μL of 50 mM mgcl2 (Biolino), 0.2 μL 500 μ tag DNA polymerase and 2.0 μL of 2.5 mM dNTPs (Biolino); 1.0 μL of 10 μM each primer, 16.05 μ of 500 ml and 1.0 μL DMSO (dimethly sulfoxide) were used to carry out the PCR amplification with DEPC-treated water (in vitrogen corporation). Routine PCR cycling profile was used for the reaction and involved 940C cycle for 2 minutes, another 40 cycles of 2 minutes and a 720C 5 minute final extension [17].

Electrophoresis was conducted using a 1.5% agarose gel containing 0.5 mg/ml ethidium bromide. A transilluminator UV light was used for photographing the plates. The amplification was repeated at least twice to ensure reproducibility.

Two ISSR primers used for this analysis were:

(AG) 9C 5'- AGA GAG AGA GAG AGA GAG C-3' and

(GA) 9C 5'-GAG AGA GAG AGA GAG AGA C-3' [17].

Fingerprint analyses was carried out using py Elph version 1.4. The Principal Coordinate analyses was done using SPSS ver. 21 while DNA gel analyzer 2010 was used for band scoring of the blood samples [18].

3. Results

3.1 PCR amplification

Figures 2 and **3** presents the results of PCR amplification products of 21 blood samples obtained from 3 goat breeds (**Figures 1**-**3**) using Agarose gel electrophoresis. L is the 100 bp DNA ladder. Samples 1–12 were obtained from the Red Sokoto breed, samples 13–16 were from the sahel white while the remaining samples 17–21 were that of the West African dwarf goat. Of the 12 samples taken from the Red Sokoto breeds, only 7 of the genomic DNA were amplified between the 400-600 bp in the DNA ladder (**Table 1**). 2 bands from SW were polymorphic and all 5 samples from WAD were polymorphic (**Figure 2**).

3.2 Band scoring of blood samples

Table 2 shows the results of band scoring indicating monomorphism or polymorphism among the 21 samples obtained from Red Sokoto (RS), Sahel white (SW) and the West African dwarf (WAD) breeds of goats in Calabar. Absence of band was indicated with zero (0) score while the presence of band was indicated with 1 score. The absence of band or 0 score in any simple loci for any primer used indicated polymorphism while presence of bands in all loci or score of 1 all through indicates a monomorphic

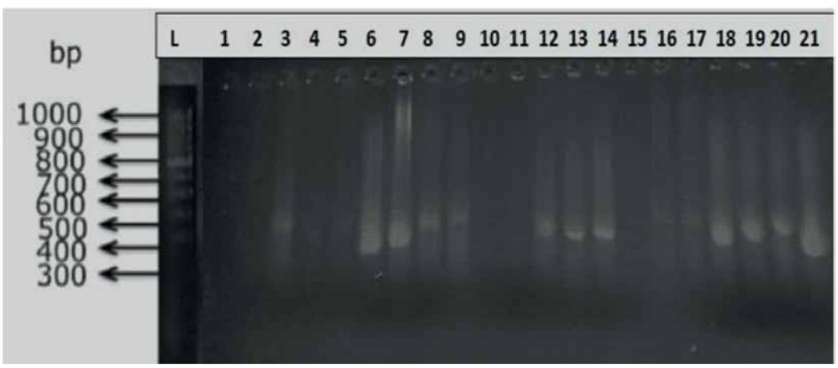

Figure 2.
Electrophoregram showing PCR products during amplification with the primers. Source: [19].

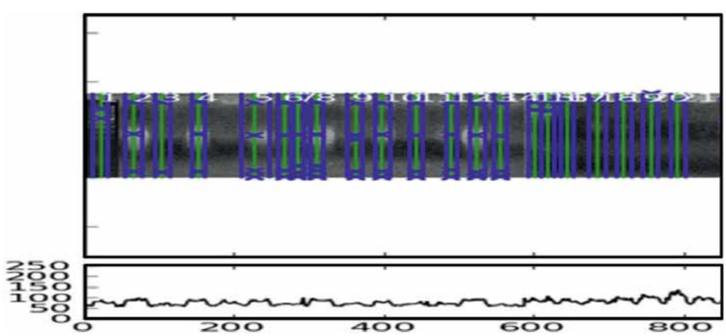

Figure 3.
DNA amplification by ISSR primers. Source: [19].

Goat breed	No. of samples	No. of amplicons	% amplification
Red Sokoto	120	70	58.33
WAD	50	50	100.00
Sahel White	40	20	50.00

Source: [19].

Table 1.
Percentage amplification of goat blood samples.

Samples (Goat breed)	Band (Lane)	Scoring condition	Samples (goat breed)	Band (Lane)	Scoring condition
Red sokoto 1	00100000100001000	polymorphic	Red sokoto 12	00010000100000111	polymorphic
Red sokoto 2	00100000100000100	polymorphic	Sahel white 1	00100000010001011	polymorphic
Red sokoto 3	00100000100001000	polymorphic	Sahel white 2	00101000000000000	polymorphic
Red sokoto 4	00100000100001001	polymorphic	Sahel white 3	01001000000000000	polymorphic
Red sokoto 5	00100000100001001	polymorphic	Sahel white 4	01000000000000000	polymorphic
Red sokoto 6	00100000100000101	polymorphic	WAD* 1	01000000000000000	polymorphic
Red sokoto 7	00100000100001011	polymorphic	WAD 2	01000000000000000	polymorphic
Red sokoto 8	00010000101001001	polymorphic	WAD 3	11,000,000,000,000,000	polymorphic
Red sokoto 9	00010000100001001	polymorphic	WAD 4	01000000000000000	polymorphic
Red sokoto 10	00100000100001001	polymorphic	WAD 5	01000000100000000	polymorphic
Red sokoto 11	00100000100001001	polymorphic			

**WAD = West African dwarf goat.*

Table 2.
Band scoring showing polymorphism for all 21 samples obtained from 3 breeds of goats.

condition. Thus, as shown in **Table 2**, all the 21 samples from the 3 goat breeds were all polymorphic showing great genetic variations between the three breeds.

3.3 Population differentiation

Table 3 presents the results of principal component analysis (PCoA) generated from 5 principal components which anchors of the molecular data generated. Principal component 1 contributed 31.21% to the total molecular variability observed

Primers	NPB	TBN	MAF	No. of Alleles		Gene diversity Polymorphism % PIC		
Primer	**1**	**1**	**3**	**0.43**	**6**	**0.568**	**74.02**	**0.654**
Primer	2	1	3	0.36	8	0.793	27.00	0.769
Primer	3	3	3	0.24	9	0.852	53.45	0.834
Primer	4	2	4	0.26	10	0.889	61.30	0.813
Primer	5	2	4	0.26	10	0.884	88.23	0.782
Primer	6	4	8	0.30	10	0.766	59.23	0.692
Primer	7	5	10	0.60	9	0.754	51.10	0.710
Primer	8	4	5	0.36	8	0.480	26.54	0.365
Primer	9	4	6	0.28	8	0.748	71.00	0.709
Primer	10	1	4	0.32	9	0.835	75.80	0.818
Primer	11	1	4	0.26	7	0.768	79.00	0.760
Primer	12	4	5	0.24	9	0.768	65.00	0.760
Primer	13	4	5	0.34	8	0.860	65.40	0.654
Primer	14	2	4	0.33	9	0.772	45.30	0.453
Primer	15	1	2	0.44	6	0.564	32.40	0.324
Primer	16	1	2	0.42	8	0.556	45.53	0.543
Primer	17	1	2	0.21	12	0.678	65.44	0.654

KEY: NPB = Number of polymorphic bands; TBN = Total number of bands; Mi = Marker Index; MAF = Major Allelic Frequency; PIC = polymorphic information content.

Table 3.
Genetic diversity analysis for 21 samples obtained from three breeds of goats.

among the breeds of goats evaluated. The results also differentiated the sample population into four different population structures as shown in **Figure 3**.

The principal coordinate analysis threats an edge length sum of 4.6177, a mean error of −0.001, a mean absolute error of 0.0696, maximum absolute error of 0.26007 and a mean square error of 0.0085, with a cophenetic (r) value of 0.9645 as fit criterion for the population differentiation.

3.4 Percentage variability

Figure 4 presents the variability results among and within the investigated goat breeds. 100% variability was singled out within the species attributable to variations in the DNA molecules while 0% variability recorded among populations was attributable to environmental influence.

As presented in **Table 3**, primer 8 produced the least gene diversity index of 0.480 among the samples while the highest gene diversity of 0.889 was obtained with ISSR primer 4. Generally, the results of gene diversity as revealed by the ISSR primers was high for most of the primers. Gene diversity of 0.852, 0.889, 0.884, 0.835 and 0.860 were revealed by ISSR primers 3,4,5, 10 and 11. Gene diversity of 0.793, 0.766, 0.754, 0.748, 0.768, 0.768, and 0.772 were revealed by ISSR primers 2,6,7,9,11,12 and 13 while ISSR primers 1,8,15,16 and 17 revealed gene diversities of 0.568, 0.480, 0.564, 0.556 and 0.678 respectively. The high gene diversity observed among the goat samples is an indication of high genetic variability existing among the breeds evaluated (**Figure 5**).

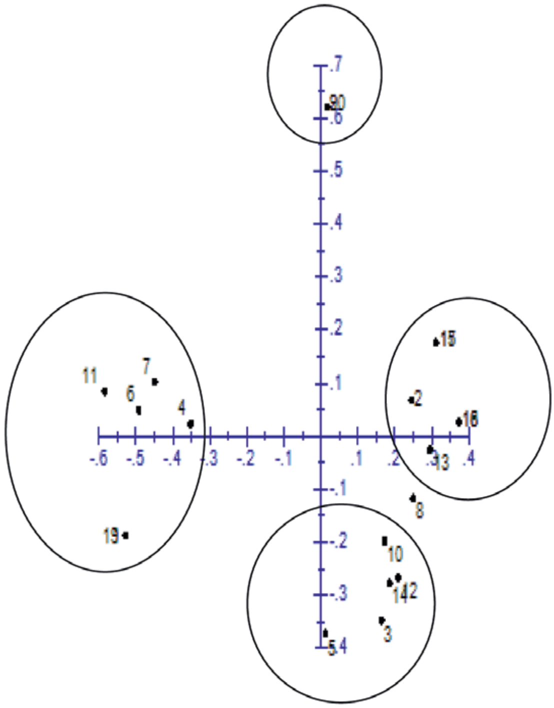

Figure 4.
Scattered plots showing population differentiation among 21 samples collected from 3 breeds of goats.

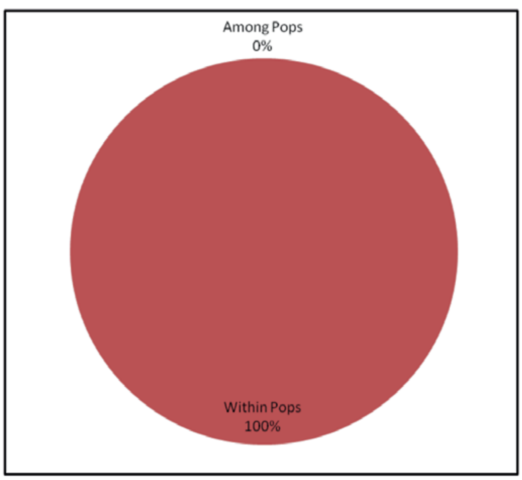

Figure 5.
Percentage variability among and within populations.

4. Discussions

The experimental goats showed variability in genetic characteristics and the results indicated the effectiveness of ISSR analysis in detecting polymorphisms [20]. The electropherogram in **Figure 1** reveals that out of the 21 samples evaluated, 15 amplified with the ISSR primers used between 300 and 1000 bps of DNA ladder. 58.33% amplification was observed from the RS population and 50% of the samples taken from the SW breed were amplified by the primers at 400-500 bp DNA ladder size (**Figure 1** and **Table 1**). Interestingly, as shown in **Figure 1** and **Table 1**, all the samples taken from the West African dwarf goat were amplified by the primers between 400 and 600 bps of the molecular ladder to produce a 100% amplicon. Estimation of higher level of genetic variation in the breeds might be consistent with the fact that they are highly polymorphic animals. In ref., [18] obtained values lower than the values calculated between breed band sharing (BS) here. The value for these 2 breeds obtained was lower (0.43 to 0.66) than within breed BS value, which was 0.70 to 0.93 in Malvi breed and 0.68 to 0.88 in Sahiwal breed found within similar genetic distances [18].

In this study, all the 21 samples from the 3 goat breeds were polymorphic showing great genetic variations between the three breeds (**Table 3**). Population differentiation investigations showed four population structures as seen on the scattered plots diagram (**Figure 3**). The high polymorphism of the WAD breed (100%) found in this study indicates that this goat breed has the required amount of genetic variation to make genetic improvement in the near future. This result resonates with that reported by [19] where they had 93.49% polymorphism among three goat breeds studied as well.

The percentage variability studies suggest greater genetic diversity occurred within the three populations than among individuals within the three populations (**Figure 4**). This indicates that the local goat populations are genetically differentiated along geographical localities. In ref., [21, 22] reported similar results in their research on chickens. This also agrees with results presented by [23, 24] where they reported high intra- population genetic diversity (91%), in comparison to inter-population genetic diversity among states (6.17%) and within states (2.77%). These results negates those earlier presented by [25] were they recorded a large proportion of genetic variation (87.46%) among populations while only 12.54% residing among individuals within populations in Psammochloa villosa population detected by ISSR markers too.

Inter simple sequence repeats (ISSR) amplification has been shown to be a suitable molecular marker assisted technique for DNA finger printing of the Nigerian indigenous local goat breeds. Thus in future selective breeding programs, this technique may be employed by animal breeders and other stake holders, in the improvement and conservation of the local goat population.

5. Conclusions

This DNA finger printing investigation of three goats breeds in Cross River state, Nigeria, have shown that the indigenous goats (Capra aegegrus hircus) found within the Calabar environs are genetically different and do not have any evolutionary relatedness.

It will therefore be necessary to recommend that an indepth breeding and conservation program for the Red Sokoto, WAD and White Sahel breeds of goats be put in place by the Cross River State government and/or individuals to boost supplies of mutton varieties for both local and international consumption. Other aspects of molecular studies, like the evolutionary trees, for these breeds can also be explored. There's need for Inbreeding programs among the goat breeds to be initiated too for sustainability and perpetration of these goat breeds.

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Section 3

Reproduction and Biotechnology

Chapter 5

Application of Biotechnology and Husbandry Practices for the Conservation, Characterization and Enhancement of Production Potential of Available Goat Genetic Resource in Bangladesh

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Abstract

A goat is a small ruminant found across the globe. However, each and every type of goat has some unique characteristics and is popular for specific reasons in a specific area. The Black Bengal goat is the only recognized goat breed in Bangladesh and is famous for its high fertility, prolificacy, superior skin and meat quality, early sexual maturity, disease resistance and short kidding interval. In this chapter, we focused on available goat genetic resources in Bangladesh, breed characteristics, morphometric characterization, husbandry practices, feed and nutrition used for goat production, productive and reproductive performances under subsistence farming system, disease and health management, biotechnological approach for conservation like estrus synchronization, semen quality analysis, cryopreservation of semen, Artificial insemination, in vitro embryo production of embryos and multiple ovulation and embryo transfer. Moreover, the contribution of goat production in poverty alleviation and women empowerment in Bangladesh was also highlighted. Thereafter, constraints on goat production and future recommendations for sustainable goat production in Bangladesh were given.

Keywords: goat conservation, biotechnological and husbandry practices, Black Bengal goat, cryopreservation, MOET

1. Introduction

Goats are economically very important and promising animal genetic resources in developing countries, especially in Asia and Africa [1]. Goats are preferred for rearing especially in small holding farming systems due to its unique ability to adapt and maintain them in harsh environments [2]. They are also known as the "poor man's cow" for their significant contribution to the poor man's economy [3]. Archeological evidence indicates that the goat was one of the first animals to be domesticated by humans around 10,000 years ago at the dawn of the Neolithic period in the Fertile Crescent [4, 5]. The tropical and subtropical climate in association with topography provides a unique habitat for goats [6]. There are about 300 breeds and varieties of goats domesticated in the Indian subcontinent [2]. Like other domestic goat breeds in South Asia, the Bengal goat is believed to be derived from the wild bezoar of Pasang (Capra aegagrus) with infiltrated blood from markhor (Capra falconeri) [7].

Black Bengal, the only recognized goat breed of Bangladesh, is known for its excellence in reproductive capabilities and production of quality meat [8]. It is one of the most compliant, all-around adjusted, early maturing, prolific, productive, and tropical disease—resistant goat types of the world [9]. Goat meat is more expensive as compared to other livestock and poultry meats [8]. They also contributed to the GDP of Bangladesh by producing quality meat and elegant leather that earns a lot of foreign currency; income generation and poverty alleviation, creating employment opportunities in rural areas as well as cash income for empowering the poor and destitute women [10]. For rearing goats, a minimum investment of money is required, even without specific arrangement of housing, grazing on barren and road-side grassland and least homemade supplied feed (rice gruel, boiled rice, skins of vegetables etc.) in the Indian subcontinent. In addition, goats are fed on the leaves of jackfruits, which are available in most of the rearing areas in Bangladesh [11]. Since goats (Capra hircus) can utilize fibrous plant materials to produce meat, which offers a reliable source of animal protein in developing countries, their abundance may have led to an increasing preference for goat meat in developed countries [12, 13].

2. Methodology

Bangladesh is a hot humid country which lies between 88°01′ to 92°41′ east longitude and 20°34′ to 26°38′ north latitude. Average temperatures in winter raged from 11°C (Min.) to 29°C (Max.) whereas average summer temperatures are 21°C (Min.) and 34°C (Max.). Annual rainfall ranges from 1194 to 3454 mm. The highest humidity is 80–100% in August–September and the lowest is 36% (February–March) [14].

Goat keepers usually reared the goats under a semi-intensive management system in traditional houses. Bucks and does were kept separated tethered by rope and allowed to graze in roadside grass and available pasture land near the farmer's house. Vegetable kitchen wastes, leftovers from family meals and tree leaves were also fed to the goats. Traditionally concentrate feeds @ 200 g/day were fed only to pregnant and lactating does [15]. Availability of drinking water was ensured all the time.

Measurements of the morphometric characteristics were taken according to [15]. Body weights at birth, 3, 6, 9 and 12 months of age were measured using the weighing balance based on different factors (sex of kid, type of birth, parity of dam, season of the year). The year was divided into three seasons namely winter (November–February), summer (March–June) and rainy (July–October) [16].

Among the reproductive parameters, age at first heat, age at first kidding, service per conception, gestation length, litter size, post-partum heat period and kidding interval were measured according to [1].

Semen collection was done with an artificial vagina (AV) maintaining an optimum temperature of about 41–43°C. Each ejaculate was evaluated for sperm motility, concentration, viability and morphology immediately [17]. After evaluation, semen aliquots were diluted by Triladyl, Andromed and Tris-based diluter separately to obtain a final concentration of 100 million spermatozoa per dose and then filled manually into 0.50-ml straws. One part of the evaluated extended semen was used for AI as fresh semen and another part was used for cryopreservation in liquid nitrogen using the standard protocol [18, 19]. The motility, morphology, viability and membrane integrity of fresh diluted and fresh-thawed semen were evaluated critically. Artificial insemination was done 24 hours [20] after the visible sign of natural or synchronized estrus. It is noteworthy to mention that successful synchronization of estrus was performed by using intramuscular injection of either progesterone or synthetic PGF2α analogue (Dinoprost®) in Black Bengal does [21, 22]. Does were closely monitored for up to 48 hours to record the signs of synchronized estrus behavior. Fertility after AI was calculated as the percentage of inseminated females actually kidding [18]. On the other hand, for multiple ovulation and embryo transfer (MOET), Black Bengal goats (BBGs) were synchronized with Gabbrostim® (Alfaprostol, VETEM, Italy @ 2-mg equivalent to 1 ml/goat), superovulation with PMSG (Folligon®, Intervet International B.V, Holland @ 900 IU, 800 IU and 700 IU, respectively) and test the efficacy of the dose. A surgical procedure was used to flush the embryos [23].

For *In vitro* production of embryos, goat ovaries were collected from a local slaughterhouse, processed and COCs were collected in three techniques (puncture, slicing and aspiration) and each graded into four grades as described [24]. Normal COCs (A and B grade) were transferred into the maturation medium and kept in a CO_2 incubator at 38.5°C with 5% carbon dioxide for 22 hours. About 15–20 matured oocytes were transferred to each of the sperm drops (sperm concentration 12.5 × 106 per ml) and incubated for 5 hours. Thereafter, the fertilized oocytes were transferred to another culture drop (600 μl) of TCM-199 with 5% FCS and kept in CO_2 incubator. The development was checked in every 48 hrs and the culture was continued up to 6–7 days [25].

In statistical analyses of the data, analysis of variance (ANOVA) was performed using a completely randomized design (CRD) [26] by the Statistical Analysis System (SAS, 1998) package program. Significant differences between the mean values were separated by Duncan's Multiple Range Test (DMRT) [27].

3. Results and discussion

3.1 Available goat genetic resources

BBG is the most well-known perceived goat breed speaking to over 90% of the all-out goats of the nation [28]. Although various types of goats are available in Bangladesh, BBGs are the most popular and dominantly (almost 90%) distributed throughout the country. Jamunapari goats concentrated in the northern and northeastern parts, Beetal, Sirohi and their crosses in the western part of Bangladesh [29, 30].

3.2 Breed characteristics

BBG is a dwarf goat breed and known to be famous for its high adaptability, fertility, prolificacy, delicious meat and superior skin [12, 31]. BBG is also reputed for its early sexual maturity, better resistance against common diseases, low kidding interval. In spite of having the above qualities, they are inferior in some economic traits such as birth weight, growth rates, milk yield, and kid survivability [9].

3.3 Morphometric characterization of Black Bengal Goat

Morphometric measurement is conducted for the characterization of the breeds of animals as well as the assessment of carcass quantity. Morphometric characterization contributes to the improvement of animal genetic resources in the context of country-level implementation [32]. Morphometric measurement of adult BBG is shown in **Table 1**.

3.4 Husbandry practices

Due to the hardy nature; resistance to diseases and better adaptability BBGs can reproduce and thereby thrive well under various types of climatic conditions [23]. The poor farmers mainly keep goats in a semi-intensive production system without any supplementation [6]. The majority of landless farmers opted to construct their farm sheds using natural materials such as bamboo, wood or occasionally coconut and straw for the roof. Some of the sheds were constructed of mud and earth. Some farmers put their goats under their beds in the same rooms where they slept [3].

The production system of BBGs in Bangladesh is generally characterized by poor feeding, housing, breeding and health management and consequently low return from sale.

Traits	Measurements
Body weight	14.05 ± 0.14 to 15.37 ± 0.23 kg [15] 16.56 ± 0.57 kg [33]
Body length	47.83 ± 0.75 cm [33] 46.50 ± 0.77 cm [34]
Height at wither	48.50 ± 0.42 cm [35] 47.92 ± 0.76 cm [33]
Heart girth	59.08 ± 0.87 cm [33] 55.70 ± 0.20 cm [34]
Ear length	14.21 ± 0.09 to 15.02 ± 0.16 cm [15] 12.69 ± 0.27 cm [33]
Ear breadth	6.02 ± 0.04 to 6.20 ± 0.04 cm [15] 5.70 ± 0.20 cm [34]
Head length	16.67 ± 0.26 cm [33] 15.10 ± 0.56 cm [34]
Head breath	10.51 ± 0.06 to 11.56 ± 0.07 cm [15] 12.33 ± 0.34 cm at 12 month [33]
Tail length	10.25 ± 0.31 cm [33] 9.80 ± 0.20 cm [34]
Scrotal circumference	19.72 ± 0.33 cm [33] 19.60 ± 0.24 cm [34]
Testicular length	9.80 ± 0.37 cm [34]

Table 1.
Morphometric measurement of Black Bengal Goats in Bangladesh.

3.4.1 Feed and nutrition used for goat production

Goats are excellent in utilizing tree leaves if provided properly. In terms of the availability of grazing land to the ruminant livestock, the stocking rate is high and supplementation of cereal grain and by-products is a costly proposition to goats for achieving higher productivity [36]. Availability of forages is not constant throughout the year and varies with season particularly, during the cropping seasons when more land is bought under cultivation.

Green grass does not fulfill the appetite and nutrient requirements as a sole feed [37]. Most of the farmers (82%) supplied concentrate feed with the green grass for their goats while very few farmers supplied green grass alone to their goats [38]. Some goat farmers gathered various feed items (wheat bran, broken rice, rice polish, oil cake, and so on) and blended a balanced diet on their farm premises [3]. Most of the farmers used concentrate feed once in a day with green grass and supplied water. Major sources of drinking water for goats were tube well and most of the farmers grazed their goats [39]. The majority of farmers preferred roadside grazing (86.7%) due to enough natural grass around their garden whereas only 8.3% cultivated high-yielding fodder on their own land [3] for feeding the goats. Farmers supplied 2.63 ± 0.05 kg/day of green grass, 60.00 ± 5.86 g/day concentrate and 0.62 ± 0.03 kg/day of tree leaves per animal during the lactation stage [38]. Concentrate supplementation is undoubtedly important to meet up the nutrient requirements, and to get the best result it can be supplemented up to 30% of the required DM. Under the stall feeding system, a concentrate supplementation with 15.60% CP is recommended for improving the growth performance of BBGs in Bangladesh [37].

3.4.2 Disease and health management

Hot and humid conditions in Bangladesh favor various diseases [40, 41]. The disease impairs the productivity of animals and incurs huge veterinary costs. The productivity of densely populated goats is poor due to the incidence of disease [42]. The common causes for goat morbidity and mortality in rural areas were: (a) viral diseases such as PPR, contagious ecthyma, goat pox and viral pneumonia; (b) bacterial diseases like brucellosis, tetanus, enterotoxaemia, mastitis and metritis; (c) fungal diseases such as ringworm infection and (d) rickettsial infections like conjunctivitis [43].

Among these infectious diseases, *Peste des petitis ruminants* (PPR) has become an important disease due to its effect on direct economic losses. PPR is an acute and extremely infectious viral disease that severely affects goats. The common symptoms were high fever, mucopurulent nasal and ocular discharge, pneumonia, necrosis, erosive stomatitis, ulceration of mucous membranes and inflammation of GI tract resulting in severe diarrhea. Age categories of goats, sex, breed and seasonal influence were found to be significantly associated ($p < 0.01$) with the prevalence of PPR. The susceptibility of BBGs to PPR was higher than other breeds [44].

Among the seasons of the year, the occurrence of various infectious diseases was higher in the rainy season (36.43%) followed by the winter season (34.94%) and summer season (28.62%). In respect of sex, the female goat was found to be more susceptible (64.22%) than the male (35.77%) [45].

The highest incidence of gastro-intestinal infection was diarrhea (31.1%) and the second highest incidence was pneumonia (27.4%). Several other diseases like lameness (9.0%), mange (6.2%), contagious ecthyma (4.4%), malnutrition (3.2%), fever (2.7%), conjunctivitis (2.6%), bloat (2.1%), abortion (1.7%), mastitis (1.7%), tympany (1.5%), abscess (1.1%), actinomycosis (1.1%), poisoning (0.8%), retained placenta (0.6%) and urolithiasis (0.4%) [46]. Large flock size was more infected to parasitic infestation (both by ecto- and endoparasites) than the smaller ones and this is due to direct contact, overcrowding and unhygienic condition of the goat farm. Usually, goats are maintained on the muddy floor in rural areas. Goats maintained on the muddy floor were infected more with parasitic infestation than the slatted floor and this may be explained as due to low level of hygiene and favored reinfestation [46]. Goats often suffer from a wide variety of surgical affections; e.g., gid disease, wound, urolithiasis, lymphadenitis, subcutaneous cyst, fracture, myiasis, bloat and so on and all these are curable if surgical intervention is performed at an appropriate time [47, 48].

Kid mortality was found 15.0 ± 0.50% in semi-intensive conditions and 10.07 ± 0.32% in extensive conditions [49] and the average kid mortality rate was 12.88% at farmers' houses [50]. Kid's mortality was due to infectious disease (63%), predators (10%), mechanical (4%) and congenital (1%). Among the infectious diseases, kid's mortality was recorded as 30, 27, 23, 17 and 2% by diarrhea, pneumonia, bloat, enterotoxaemia

Factors	**Body wt. (kg)**				
	Birth	**3-month**	**6-month**	**9-month**	**12-month**
Sex of kid					
Male	1.3 ± 0.10 [16] 1.16 ± 0.07 [55]	5.20 ± 0.6 [16] 5.70 ± 0.21 [55]	8. 90 ± 0.8 [16] 8.65 ± 0.11 [55]	13.20 ± 0.60 [16] 11.55 ± 0.33 [55]	17.9 ± 0.70 [16]
Female	1.2 ± 0.1 [16] 1.07 ± 0.07 [55]	4.50 ± 0.6 [15] 5.01 ± 0.17 [55]	8.10 ± 0.8 [16] 7.40 ± 0.21 [55]	10.10 ± 0.5 [16] 9.93 ± 0.30 [55]	12.10 ± 0.5 [16]
Type of birth					
Single	1.40 ± 0.1 [16] 1.11 ± 0.01 [55]	5.50 ± 0.5 [16] 5.48 ± 0.19 [55]	8.60 ± 0.5 [16] 8.58 ± 0.13 [55]	12.70 ± 0.7 [16] 11.66 ± 0.31 [55]	16.50 ± 0.5 [16]
Twin	1.30 ± 0.1 [16] 1.09 ± 0.01 [55]	5.3 ± 0.4 [16] 5.23 ± 0.16 [55]	7.70 ± 0.4 [16] 7.76 ± 0.16 [55]	11.10 ± 0.1 [16] 11.56 ± 0.28 [55]	13.30 ± 0.70 [16]
Triplets	1.10 ± 0.1 [16] 0.86 ± 0.01 [55]	4.6 ± 1.5 [16] 4.78 ± 0.11 [55]	7.60 ± 1.1 [16] 5.57 ± 0.16 [55]	9.90 ± 1.3 [16] 10.72 ± 0.24 [55]	12.1 ± 1.30 [16]
Parity of dam					
First	1.10 ± 0.1 [16] 1.03 ± 0.10 [55]	4.40 ± 0.5 [16] 4.70 ± 0.11 [55]	7.70 ± 0.7 [16] 7.76 ± 0.16 [55]	11.50 ± 0.6 [16] 11.06 ± 0.23 [55]	14.80 ± 1.5 [16]
Second	1.10 ± 0.10 [16] 1.17 ± 0.17 [55]	5.60 ± 0.60 [16] 5.62 ± 0.18 [55]	8.50 ± 0.90 [16] 8.51 ± 0.13 [55]	11.20 ± 1.20 [16] 11.01 ± 0.22 [55]	13.60 ± 1.0 [16]
Third	1.30 ± 0.10 [16] 1.24 ± 0.10 [55]	5.70 ± 0.7 [16] 5.70 ± 0.17 [55]	8.10 ± 1.0 [16] 8.33 ± 0.13 [55]	10.60 ± 1.30 [16] 10.63 ± 0.18 [55]	12.10 ± 1.50 [16]
Fourth	1.50 ± 0.10000 [16]	6.90 ± 0.2 [16]	8.50 ± 0.2 [16]	10.8 ± 1.8 [16]	12.62 ± 1.93 [16]
Season of birth					
Winter	1.30 ± 0.10 [16]	5.44 ± 0.62 [16]	8.50 ± 0.7 [16]	12.70 ± 0.6 [16]	15.49 ± 0.70 [16]
Summer	1.30 ± 0.1 [16]	5.32 ± 0.63 [16]	8.10 ± 0.8 [16]	10.10 ± 0.5 [16]	12.3 ± 0.60 [16]
Rainy	1.22 ± 0.06 [16]	3.64 ± 0.94 [16]	5.70 ± 1.24 [16]	9.69 ± 0.32 [16]	14.49 ± 0.31 [16]

Table 2.
Body weight at different ages of Black Bengal goat in respect of sex, type of birth, parity, and season of birth.

and ecthyma, respectively [51]. Overall adult mortality was 12.69% [51]. Better housing, management, routine vaccination and timely deworming can reduce mortality as well as ensure better health management and higher productivity.

3.5 Productive performance

Adult body weight is an important economic factor that influences the growth and production pattern of any goat enterprise and has more influence mainly on the growth behavior of kids [52]. Average daily gain (g/d) was 43.29 ± 1.82 at birth to 3 months, 39.50 ± 1.91 at 3–6 months, 26.48 ± 1.99 at 6–9 months and 23.04 ± 1.30 at 9–12 months in the semi-intensive system of rearing in rural areas [53]. On the other hand, in the fully intensive management system body weight gain were 66.34 ± 1.69, 41.54 ± 2.02, 49.97 ± 3.10 and 39.28 ± 4.35 g/d, respectively. Average daily milk yield, lactation length and total milk per lactation were 287.7 ml/d, 61.5 days and 19129.40 ml, respectively [54]. Body weight differed in respect of sex, type of birth, parity and season of birth which is illustrated in **Table 2**.

3.6 Reproductive performance

Reproductive efficiency is always considered to be the most vital factor ensuring the increase in productivity to a certain environmental condition [56]. One of the most favorable attributes of the BBG is its year-round breeding, high rate of reproduction and prolificacy. It reaches puberty earlier by 6 months and gives birth 2–3 kids at a time. The overall reproductive performance of the BBG is shown in **Table 3**.

3.6.1 Seminal attributes of Black Bengal buck

Male fertility is an important issue in caprine reproduction. As a result, determining male fertility before breeding is critical for breeding success. The most efficient

Parameter	Performance
Age at puberty (days)	182.7 ± 7.25 [54] 209.00 ± 32.25 [56]
Age at first service (days)	187.56 ± 8.33 [54]
Service per conception (No.)	1.46 ± 0.53 [57] 1.37 ± 0.03 [54]
Age at first kidding (month)	13.85 ± 0.41 [57] 401.50 ± 32.08 days [56]
Gestation length (days)	146.00 ± 2.15 [57] 142.45 ± 0.31 [54]
Litter size (No.)	1.92 ± 0.90 [57] 1.75 ± 0.03 [54]
Kidding interval (days)	177.00 ± 7.44 [57] 188.01 ± 2.14 [54]
Post partum heat period (days)	33.39 ± 1.82 [54] 47.50 ± 0.87 days [1]

Table 3.
Reproductive performance of Black Bengal Goat.

Parameters	Mean ± SE
Ejaculate volume (ml)	0.58 ± 0.17 to 1.04 ± 1.1 [65] 0.37 ± 0.02 to 0.53 ± 0.03 [66] 0.46 ± 0.08 to 0.71 ± 0.06 [67]
Concentration (10^9/ml)	2.11 ± 0.09 to 2.69 ± 0.08 [66] 2.4 to 2.7 [67]
Fresh semen motility (%)	80.83 ± 3.5 [68] 75.00 ± 5.3 [69] 72.65 ± 0.56 [59]
Live spermatozoa (%)	87.58 ± 0.96 to 92.95 ± 0.74 [65] 86.16 ± 1.54 to 89.22 ± 0.79 [67]
Normal spermatozoa (%)	91.39 ± 0.24% [59] 87.17 ± 2.40 to 91.85 ± 1.38% [65] 90.44 ± 0.27 to 91.41 ± 0.32 [67]
Head abnormalities (%)	2.50 ± 1.70 [68] 1.40 ± 1.30 [69]
Mid piece abnormalities (%)	6.90 ± 2.50 [68]
Tail abnormalities (%)	7.10 ± 2.60 [68]

Table 4.
Characteristics of Black Bengal Goat semen.

parameter for selecting breeding buck is the semen quality. The evaluation of sperm motility and morphology is an essential parameter in the examination of sperm quality and the establishment of a correlation between semen quality and fertility [58]. Fertilizing capacity of semen has always been regarded as one of the key factors in running an AI program [59]. Semen quality and attributes were influenced by body weight, body condition score, age, scrotal circumference, testicular circumference, breed, management, climatic, nutrition, technique for semen assortment and level of sexual incitement [60–63]. Like rams, buck ejaculates are small in volume with a high concentration of spermatozoa [64]. The characteristics of Black Bengal buck semen are shown in **Table 4**. Sperm motility accounts for around 10–15% of the total variation in male fertility measured by the non-return rate (NRR) [70].

3.7 Application of biotechnological tools

3.7.1 Estrus synchronization

Estrus synchronization is an essential element for the improvement of reproductive efficiencies through implementing fixed-time artificial insemination (AI), MOET, laparoscopic ovum pick up (LOPU), etc. As the duration of the estrous cycle and estrus period is variable, therefore, estrus synchronization is an important tool to increase reproductive efficiency [71]. Approaches toward synchronizing estrus are done by the manipulation of either the luteal or the follicular phase of the estrous cycle. Strategies can be employed to extend the luteal phase by supplying exogenous progesterone analogs in conjunction with or without gonadotropins or to shorten this phase by prematurely regressing existing corpora luteal through using prostaglandin (PGF2α) or by the combination of both techniques. Exogenous hormones are used to modify the physiological chain of events involved in the sexual cycle, while the non-hormonal methods of oestrus synchronization involve the use of light control or exposure to a male [72].

Worldwide, progestogen or progesterone treatment in the form of vaginal devices (Sponges/CIDR) or ear implants is usually used. In Bangladesh, two synchronization methods for goats have been evaluated under research conditions and concluded that 12.5 and 15.0 mg progesterone could be used as an effective way for estrus synchronization in Black Bengal does [21]. Another report showed that synchronization of estrus with dinoprost®, a synthetic analog of 1 ml/does PGF2α may be suitable for estrus synchronization of BBG [22]. Besides these, synchronization of BBG was also done successfully with Alfaprostol (Gabbrostim®, VETEM, Italy) and luprostiol (Prosolvin®, Intervet International, Netherlands) at the dose rate of 2 and 7.5 mg, equivalent to 1 ml/goat, respectively [73].

3.7.2 Cryopreservation of semen

Cryopreservation is the method that preserves structurally intact living cells at very low temperatures and during this process, all metabolic activities are minimized due to the freezing and the low temperature of storage [74, 75]. This technique is important for the breed conservation process. Furthermore, this technology can contribute to the extension of artificial insemination, which is a landmark technology in the modern livestock industry [76]. The success of semen preservation is markedly dependent on the semen quality and the major parameters include sperm morphology, sperm concentration and sperm motility [77].

A standardized freezing procedure for goat sperm includes semen samples collection, assessment of semen samples, semen extension and packaging into plastic straws, cooling and freezing of semen. But, several limiting factors such as: semen concentration, storage temperature (optimum freezing and thawing rates), the composition of extension media and cryoprotectants used during the freezing process are responsible for the low quality of goat cryopreserved semen. For cryopreservation of goat semen, different extenders and freezing procedures have been used [78–81]. It was revealed that motility of the frozen semen differed according to the kinds of diluter (Triladyl: before dilution 81.7 ± 1.05% and post thawed 42.50 ± 1.71%, Andromed 83.3 ± 0.589% and 34.67 ± 1.67% and Tris diluter 80.1 ± 0.825% and 28.71 ± 1.55%, respectively) [82]. A comparative study on fresh and frozen–thawed semen quality revealed that sperm motility ranged from 70.83 ± 1.54 to 74.23 ± 1.59% vs. 44.17 ± 2.39 to 52.31 ± 1.08% in fresh and frozen–thawed semen of BBG. On the other hand, sperm abnormalities were found 8.82 ± 0.24 to 9.71 ± 0.52% in fresh and 11.18 ± 0.42 to 16.55 ± 0.09% in frozen–thawed semen, respectively [18]. In case of membrane integrity, a significant difference was also observed between fresh and frozen–thawed semen. An experiment result showed that the mean membrane integrity of fresh semen was 71.9% which declined to 62% after dilution which further reduced to 58.4% in case of post-thawed semen of BBG [19]. Semen cryopreservation exhibited detrimental effects on post-thaw semen motility, plasma membrane, acrosomal status and DNA integrity which ultimately affect the fertility outcome [83].

3.7.3 Artificial insemination

Artificial insemination (AI) is the most commonly applied means of assisted reproduction in domestic species. AI remained the main vehicle that offers a relatively simple and easy method for the dissemination of valuable genes rapidly to improve production traits. Furthermore, it avoids dissemination of various infectious and venereal diseases. The efficiency of AI is counterbalanced by two limitations resulting from the less number of breeding males used, which decreased the genetic variation, genetic defects or uncontrolled (or unknown) diseases could spread, and the inbreeding coefficient might be increased that affecting maternal traits [84].

For the implementation of AI, the collection of semen from male goats requires a teaser and an artificial vagina and it is a fully established technique [85]. Three methods of semen preservation (fresh, refrigerated and frozen) and three techniques of insemination (vaginal, cervical and intrauterine) are used worldwide in goats [85–87]. The use of two different forms like fresh and frozen–thawed semen influenced the fertility rate of goats. When artificial insemination was performed with fresh semen, the kidding rate was found higher than AI with Frozen–thawed semen [18]. The overall kidding rate of BBG achieved with fresh semen was 59.8%, using frozen–thawed semen it was found 43.9% [18]. On the other hand, when the conception rate was compared between the two kinds of frozen semen (diluted with Egg YC and Tris) it was revealed that the kind of semen had no significant effect ($p > 0.05$) on conception rate [88]. Similarly, the pregnancy rate did not differ when AI was done with the semen processed with different concentrations of egg yolk [89]. On the other hand, on the basis of the liquid preservation periods at 4°C, a kidding percentage was 69% (53 of 77), 68% (17 of 25) and 56% (14 of 25) after insemination with day 1, day 2 and day 3 semen, respectively [90].

It is a bitter truth that though AI has gained widespread acceptance in the cattle industries of most developed countries, it has not yet received such acceptance in the goat industries of Bangladesh [91]. With the exception of one region (Mymensingh), where 12% of farmers relied on artificial insemination in goats whereas almost all farmers (100%) of the country had to rely on natural mating to serve their does [92].

3.7.4 Multiple ovulation and embryo transfer (MOET)

In cross-breeding program, male germplasm through artificial insemination program has made tremendous progress in domestic species whereas MOET is considered as an effective means of increasing the contribution of superior females to breeding programs and it is also an essential procedure of embryo biotechnology [93]. MOET protocols have resulted in significant improvements in domestic animals over the last two decades; however, unlike cattle, goat MOET is underdeveloped, as collection and transfer of embryos via surgical procedures have limited advantages in small ruminants like a goat. In larger domesticated animals such as the cow and horse, manipulation of the genital tract per rectum facilitates the collection and transfer of embryos through the cervical canal and into the uterine horn ipsilateral to the ovulating ovary, whereas, the application of successful MOET in small ruminants has been constrained by the tightly folded form of the cervix, the variable ovarian response to various super ovulatory treatments, and the need for labor to handle animals, especially during large-scale production [94, 95].

MOET aims to fertilize multiple oocytes in a shorter time to produce a large number of viable embryos, that are transferred into the recipient animal which leads to a higher birth rate [96, 97]. The basis of this technology is to synchronize estrus, hormonal stimulation and AI of donors, thereafter collect the viable embryos and transfer them in the recipient animal by surgical procedure [98, 99]. Focusing on its beneficial effects, a series of works in goat MOET has been done around the world. But very few published work has been reported on multiple ovulation and embryo transfer in BBG in

Bangladesh where they determine the responses of BBG following synchronization with Gabbrostim® (Alfaprostol, VETEM, Italy @ 2-mg equivalent to 1 ml/goat), superovulation with PMSG (Folligon®, Intervet International B.V, Holland at the dose rate of 900, 800 and 700 IU, respectively) and embryo collection with the surgical procedure was used to flush the embryos. The results of the experiment found that better super ovulatory response with 900 IU (13.6 ± 3.6) PMSG and the recovered embryos were 100% fertile [89]. However, MOET has not yet become a widespread tool for genetic improvement for a variety of reasons including its costs, technical demands and variable and unpredictable efficiency [100].

3.7.5 In vitro embryo production (IVP)

IVP is a very promising technique that offers an alternative to superovulation as an excellent source of low-cost embryos for transfer and manipulation purposes. It is a multistep methodology comprising the following procedures: [1] retrieval of oocytes from the ovary [2] *in vitro* maturation (IVM) of oocytes, [3] *in vitro* fertilization (IVF) with capacitated sperm and [4] *in vitro* culture (IVC) of zygotes to the blastocyst stage after that this could be directly transferred to the recipient animal or preserved in liquid nitrogen for long term use [101]. Moreover, IVEP from slaughterhouse oocytes represents the most convenient and cheapest source to develop basic research on oocyte maturation and cell cycle regulation, gametes recognition and fusion and regulation of early embryo development.

In Bangladesh, IVP technology in goats is new and very few research work done regarding goat IVEP including evaluation and grading of ovaries, oocyte retrieval, grading of oocytes IVM and IVF are lacking in BBGs in Bangladesh. Qualitative and quantitative assessment of ovaries from BBGs was conducted in view of IVP [102]. The average number of good quality oocytes recovered from ovaries without corpora lutea was more as compared to the ovaries with corpora lutea (CL). The number of follicles measuring 2–6 mm in diameter was found to be higher in ovaries without CL than in ovaries with functional and regressed CL [103]. Besides this, quality cumulus oocyte complexes (COCs) with a homogenous evenly granulated cytoplasm possessing multi-layers of compact cumulus cells are also important criteria for the production of goat embryos in IVP [25].

Results of investigation on the effect of collection techniques on COCs recovery indicated that aspiration of 2–6 mm diameter follicles is the most effective technique for oocyte recovery among the three techniques (puncture, slicing and aspiration) from slaughterhouse goat ovaries, however, there was no significant ($p > 0.05$) effect of COCs collection techniques on IVM and fertilization in goats [104]. Whereas other reports [105] suggested that the slashing technique is more suitable for harvesting a greater number and superior quality of COCs. The efficiency of fertilization and post-fertilization development is influenced markedly by IVM conditions [106]. Goat follicular fluid is one of the alternatives of macromolecules that can be used as supplementation in the maturation media because it is easy to get and also cheap [107]. Moreover, it is reported that goat follicular factor (gFF) has a positive effect on *in vitro* production of embryos in BBGs, and a 10% level of gFF is recommended based on the improvements observed and the associated economic benefits [108].

Besides this, it has been reported that supplementation of a protein source named bovine serum albumin (BSA) in basic medium improves maturation, fertilization, blastocyst formation and hatching rates *in vitro* embryo to the presence of a relatively high molecular weight protein which contributes to the maturation of oocytes [109–112].

Bovine serum albumin at 5% level has been recommended as a supplement for the maturation and fertilization of goat oocytes in the TCM-199 medium [113]. The efficiency of *in vitro* fertilization and subsequent development of goat embryos using fresh and frozen semen for IVF was examined and found that both fresh and frozen semen can be used for IVF and subsequent development of goat embryos [114].

3.8 Contribution of goat production in poverty alleviation and women's empowerment

Goats are highly valued for their diverse production profiles and important contributions, including their meat, milk and industrial raw materials including skin, fiber and dung. Goats play a significant role in enhancing household nutrition as well as producing employment, income and capital storage [115, 116]. The raising of goats by struggling women and poor farmers requires little financial commitment in Bangladeshi culture, according to [117] and goats are now highly regarded in Bangladesh because of their role in reducing rural poverty. Bangladesh Government has also given special emphasis and adopted a national program on BBGs for poor farmers to reduce poverty for the achievement of Millennium Development Goals (MDGs) since 2003 [118]. Bangladesh Livestock Research Institute (BLRI) developed a technology package namely "Goat rearing model for landless and small farmers", which showed that one female goat keeper could earn an annual additional income of about BDT 1455. Besides these, they also recommended that it would possible to earn around BDT 7000–12,000 per year (from the second year) from goat farms starting with five does [119]. Findings from the project "National program on poverty reduction through goat production" showed that goat rearing improved livelihood dramatically; food purchasing capacity increased from 20 to 28% per annum and uplifted the farmer's social status. Moreover, health facilities, festivals and educational status acceptance were increased by 28, 26 and 19%, respectively by goat rearing [119].

Women's empowerment, particularly at the individual level, aids in creating a foundation for social change and is a crucial prerequisite for the eradication of global poverty and the protection of human rights [120]. Compared to women in other nations, Bangladeshi women are less advantaged economically and socially. In Bangladesh, women make up roughly 50% of the population and 80% of them live in rural areas. Previously in Bangladesh, rural women were restricted to homestead

Figure 1.
(a, b): Entrepreneurship development among women through goat rearing (Photo credit: Prof. Dr. Auvijit Saha Apu).

production and post-harvest operations; but nowadays they are involved in a variety of agricultural sub-sectors such as livestock, poultry and fishing in addition to caring for children and preparing and serving meals for the family. Employment opportunities in these subsectors are growing now. Goat rearing in Bangladesh enhanced employment for men, employment for women, social dignity, and social acceptance at rates of 35, 24, 58, 26 and 23%, respectively [121]. Moreover, one recent study conducted on entrepreneurship development among women through community-based goat rearing in char areas of Bangladesh (**Figure 1a**, **b**) found that community-based goat rearing helped to develop entrepreneurship among women and 70% of women in char areas opined that their overall livelihoods have been improved. The majority of the women entrepreneurs (71.61%) received benefits from BDT 10,000 to more than BDT 20,000 which facilitated them to help their husbands during a crisis moment, can give money to their children for education, buy personal commodities [122].

4. Constraints

One of the main livestock species ensuring Bangladeshi farmers' stability of livelihood is the goat. Goats are crucial as "mobile" food assets in emergency situations [123]. During religious festivals and ceremonial gatherings, goats are frequently used as a "sacrificial" animals. The Sustainable Development Goals can be achieved in large part through goat farming. However, goat farmers face a number of challenges in Bangladesh include a lack of education, inadequate veterinary services, a lack of feed, and a lack of fodders [124]. Another problem is the prevalence of PPR and skin disease in BBGs because the farmers have little or no knowledge about the causes of these diseases [121]. Aside from these, there are some other major constraints that affect sustainable and commercial goat farming in Bangladesh, such as farmers' lack of knowledge on improved production management of goat rearing and proper feed preparation, a lack of low-cost complete feed, an acute shortage of good quality Black Bengal breeding bucks or AI facilities so that a large number of heated does remain unserved. In Bangladesh, unfortunately, the number of breeding bucks is decreasing day by day because the majority of goat farmers castrate almost all of the male calves at a young age for social and economic reasons [125]. Additionally, the use of the same buck from generation to generation has increased the likelihood of inbreeding, which lowers reproductive performance and facilitates the spread of infectious and venereal diseases [126]. Moreover, the lack of linkage between the wholesale market and farmers also affects the profitability in case of commercial farming.

5. Conclusion

Black Bengal goat (BBG) is the heritage and pride of Bangladesh. It is a dwarf breed found almost in all villages in Bangladesh. The higher demand of meat and skin in the local as well as foreign markets, focused goat enterprise as extremely important to the vulnerable group of people in the existing socio-economic conditions of the country. Due to several reasons, this breed is haphazardly crossed with an exotic breed and loses its purity. Therefore, the application of biotechnologies and modern husbandry practices should be implemented for the conservation, characterization and enhancement of the production potential of BBGs in Bangladesh.

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Conflict of interest

The authors declare no conflict of interest.

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Section 4

Animal Health

Chapter 6

Common Diseases of Goats, Treatment and Preventive Measures

Babagana Alhaji Bukar and Isa Musa Mabu

Abstract

Goat diseases are economically significant and potential to achieve many national and international assurances on food security, poverty alleviation and improved nutritional standard. These diseases pose several constraints to the development of livestock sector to a country where is endemic. This sector constitutes a quantum of significant livestock production which serves as a source of meat, milk, wool and source of income to a farmer. Although, most of these diseases are quite responding to various treatment regimens with the exception of those few microbes which largely be control through timely recognition, movement restriction, vector control and moreover the use of effective high quality vaccines.

Keywords: goats, diseases, treatment, preventive measures, common

1. Introduction

Goat diseases can cause huge economic loss to the farmers due to high intensity to goat farming with poor management practices. Factors affecting livestock production in most countries includes diseases, poor management and lack of proper breeding policies [1]. Disease is an abnormal condition that negatively affects the structure or function of a body system of an animal. Various organisms like bacteria, fungal, parasite, protozoa, rickettsia and viruses are said to caused goat diseases, low quality feeds and poor management practice can predispose to metabolic disorders, which can caused losses due to reduced productivity and death [2]. Diseases are very important to farmers and affect the production of small ruminants in several ways [3]. It incurs increase in the cost of production, reduces production rate, which directly or indirectly affects the quantity and quality of animal products and causes a great loss to the farmer. Goats are usually exposed to vulnerable diseases and harsh conditions due to nonchalant attitudes of the farmers, where they allowed their animals scavenge freely on the streets without proper monitoring and sometimes subjected to extreme starvation with little or no concern to their well-being [1]. Several factors like overpopulated herd size, less ventilation and poor management system can predispose to disease. Fomites such as water and feed troughs, as well as bedding can also transmit disease for a short time, but do not remain infectious for long periods. Goats form an integral part of animal production in most rural and urban communities, their economic advantage is primarily associated with the case of handling as it favors small scale investment minimum risk of loss and high reproductive efficiency. Livestock production is a tremendous enterprise in East African countries where about 56% of livestock wealth in Africa is maintained [4]. Goats are mainly kept for meat, milk, manure, wool and immediate source of income. In most developing countries, the owner-ship of small ruminants varied from house-holds, farmers with mixed farming activities to some landless agriculture migrant workers [5]. A sound management practice is a basic tool to maintain animal health in the production of goats. There are some human health risks directly associate with dealing with diseased animals, while some diseases affecting goats do not have any zoonotic effect to human health. Small ruminants are the main farm animals owned by the poor in most developing countries which are considered as 'mobile banks' and are reared as source of not only milk and meat for family consumption but also as source of income that can easily be utilized for paying household expenditures [6]. Efforts to improve the productivity of goats have been hindered by a variety of factors including infectious diseases that results in a countless number of animal deaths [7]. The basic knowledge about diseases and management practice at the practitioner level on goats production deems necessary. Productivity of goats is affected due to increased incidence of diseases and poor management practices. Viral diseases like PPR, goat pox, contagious ecthyma and viral pneumonia and bacterial diseases like enterotoxaemia, tetanus, brucellosis, mastitis and metritis, mycotic diseases such as dermatophytosis and rickettsial infections like conjunctivitis are common causes of goat's mortality in rural areas while, Gastrointestinal nematodiasis, fasciolopses and tape worm infestation causes less mortality but can cause severe depression in the growth and reproductive performance of goats [8]. This study therefore seeks to make an attempt to identify some common diseases of Goats and provide treatment and preventive measures to control goat diseases. In view of that, the socioeconomic aspect of the farmers, tendency to recognized common diseases (**Table 1**) and the professional methods of preventing goat diseases are established. It is also believed to be useful for scientists, extension service providers, veterinarians and para-veterinarians in designing appropriate preventive measures to minimize the risk for diseases in goat production.

Bacterial diseases	Fungal diseases	Parasitic diseases	Protozoa/ Rickettsial diseases	Viral diseases	Metabolic and nutritional diseases
Anthrax	Candidiasis	Endo parasite	Babesiosis	PPR	Mil fever
Brucellosis	Cryptococcosis	Ecto parasite	Coccidiosis	Goat pox	Ketosis
CLA	Ring worm		Theileriosis	CAE	Grain overload
CCPP	Aspergilosis		Cowdriosis	Orf	
Dermatophilosis			Anaplasmosis		
Mastitis					
Foot rot					

Table 1.
Summary of common diseases of goats.

2. Methodology

This chapter is a detailed summary of the most important common diseases of goats and this can be a guide to veterinary students, field veterinarians, animal health workers, animal scientist and goat farmers regarding the impact of these diseases. This chapter also gives out a hint on the treatment and preventive measures associated with diseases of goats. Important diseases that are zoonotic and economically important like anthrax, brucellosis, caseous lymphadenitis, contagious caprine pleuropneumonia (CCPP), dermatophilosis, foot rot, candidiasis, cryptococcosis, babesiosis, cowdriosis, anaplasmosis, Peste des petits ruminants (PPR), goat pox, ecthyma and hypocalcaemia (**Table 1**) are vividly discussed. Each disease is dealt with various subsections like definition of the diseases, etiology, transmission, clinical signs, diagnosis, treatment and preventive measures.

3. Bacterial disease of goats

3.1 Anthrax

Anthrax is an infectious zoonotic disease of wild and domestic herbivores caused by a spore- forming bacterium, which is characterized by onset of high fever, oozing of unclotted blood from natural orifice and sudden death.

Transmission: Susceptible animals get infected by ingesting spores while grazing in highly contaminated soil or through the bite of certain flies. There is report of human infection through contact with the infected animals or contaminated animal tissue or products. The bacterium also penetrates body through lesion and sometime be acquired through ingestion of poorly cooked meat from infected animals.

Etiology: the disease is caused by *Bacillus anthracis* which is an aerobic or facultative anaerobic capsulated gram-positive, rod shaped spore forming bacterium. The spores can remain viable on soil for many years.

Clinical signs: Incubation period is typically 1–20 days. Most infections are noticeable after 3–7 days. Anthrax disease may be per acute, acute, sub-acute or chronic. The per acute form most often affects cattle, sheep and goats at the start of an outbreak and is characterized by staggering, trembling, difficulty in breathing, convulsions and death. Progression of the disease is rapid and premonitory signs may go unnoticed often animals are found dead with no rigormortis (**Figure 1**, **Table 1**). Blood may fail to clot due to the toxin released by *B. anthracis*. The acute or subacute form is common in cattle, sheep and horses and manifest high fever, increased heart

Figure 1.
Absence of rigor mortis in goat with anthrax by author.

rate, excitement, depression, incoordination, cessation of rumination, low milk production, bloody discharges, respiratory distress, convulsion, and death within 48–72 hours. But the chronic form is usually seen in less susceptible species like swine.

Diagnosis: Careful microscopic examination of stained smears of blood, vesicular fluid, or edema may reveal the presence of *B. anthracis***.** Biochemical and microbiologic tests provide a definitive diagnosis. It can also be isolated from skin lesions or respiratory secretions.

Treatment: Treatment of per acute case is usually untimely because of sudden death. Good recovery can be achieved through the use of anthrax antiserum in the early stage of the disease. Oxytetracycline at the dose rate of 5miligram/kilogram body weight parenterally can be effective if used from anthrax is most often seen in less susceptible species such as swine, but it has also been reported as developing in cattle, horses, dogs and cats. Route of infection in animals is most often ingestion, rather than inhalation or inoculation via skin lesions, initial suspicions of anthrax may be raised when livestock are found dead, bloated the onset of the disease. Penicillin streptomycin (Penstrep) also found effective if given concurrently with antiserum for 5 consecutive days.

Prevention: Anthrax can be prevented through annual vaccination programs. Rapid detection and reporting, quarantine, treatment of sub clinically affected animals (post exposure prophylaxis) and burning or burial of suspect and confirmed cases may prevent spore formation.

3.2 Brucellosis

Brucellosis is a bacterial infection that can affect goats and other livestock such as sheep and cows and wild ruminants such as deer, elk and bison. Brucellosis causes abortion or stillbirth in animals. Brucellosis is one of the widest spread zoonosis transmitted by animals and in endemic areas, human brucellosis has serious public health consequences.

Etiology: Brucellosis in goats is normally caused by a Gram-negative coccobacillary rod, *Brucella melitensis* although *Brucella abortus* may also cause clinical brucellosis.

Clinical sign: *Brucella melitensis* is the most common cause of brucellosis in sheep and goats. It can cause abortion, retained placenta and swelling of the testicles. Abortion usually occur in late pregnancy in sheep and during the fourth month of pregnancy in goats (**Figure 2**, **Table 1**). Communicably, brucellosis is contagious to humans. Bacteria are present in milk, placenta, fetal fluids, fetus, vaginal discharges, semen and urine. Ruminants and other animals can shed bacteria long-term or lifelong.

Figure 2.
Abortion complicated with uterine prolapse in brucellosis. By author.

Diagnosis: History and clinical signs may be suggestive of the brucellosis. Demonstration of the bacteria in smears made from the samples of blood, bone marrow and other bod fluids can help confirming the diagnosis of the disease. Brucella can be isolated from the abomasal contents and lungs of the fetus, mammary glands, supramammary, retropharyngeal, parotid and mandibular lymph nodes and seminal vesicles by culturing on 5–10% blood or selective serum agar. Other serological methods like Serum Agglutination Test, Rose Bengal Plate Test, Enzyme Linked Immuno-Sorbent Assay (ELISA), Agar Gel Immuno-Diffusion (AGID) and Complement Fixation Test can be diagnostically used in the confirmation of brucellosis.

Treatment: There is no specific treatment of brucellosis that is successful, but long term antibiotics treatment can eliminate *B. melitensis* infections in valuable goats but the reproductive performance may be poor.

Prevention: Prompt vaccination of cattle, sheep and goats is recommended especially in endemic areas. Good hygiene practice such as milk pasteurization, proper meat processing, correct handling of stillbirths and animal carcasses are important strategy for the prevention of brucellosis in goats.

3.3 Caseous lymphadenitis (CLA)

Caseous lymphadenitis is an infectious disease caused by the bacterium *Corynebacterium pseudotuberculosis*, that affects the lymphatic system, resulting in abscesses in the lymph nodes (**Figure 3**, **Table 1**) and internal organ of Goats and Sheep.

Transmission: The disease is highly contagious that affects sheep and goats [9]. When abscess ruptures, it releases a huge number of bacteria on to the skin and wool and it results to the consequent contamination of the surrounding environment. Animals may get infected when come in contact with the affected animals or indirectly via already contaminated fomites [10]. Infected animals may contaminate feed and water, which may become source of infection. The disease is also easily spread through the materials that are used during the operation of the animals such as castration, identification with ear tags or by tattooing. It is thought to also be spread by coughing or even by flies [11].

Etiology: CLA is caused by a gram-positive, nonmotile pleomorphic rods bacterium known as *Corynebacterium pseudotuberculosis* that has a characteristic Chinese letter arrangement in the smear. When this organism successfully established in the host, it surrounds and subdue the immune system, as a result it causes chronic infection that may remain in the animal for life but not pestilent [10].

Figure 3.
Lymphnode abscess seen in clinical CLA in goat.

Clinical signs: In CLA, there is abscessation in the region of peripheral lymph nodes especially the submandibular, parotid, prescapular and prefemoral nodes, which is termed superficial or cutaneous form. The internal form of CLA more commonly presents as dyspnea, loss of weight and failure to thrive. Other clinical signs include large pus filled cyst on the neck, sides and udders, cough, purulent nasal discharge, fever and tachypnea with abnormal lung sounds may be observed.

Diagnosis: A provisional diagnosis of the disease can be based on clinical features and physical examination of lesions associated with lymphnodes. Confirmation of the disease is achieved by bacterial culture of suspected lesions and purulent materials from an intact abscess. Serologic tests are available but their reliability is unrealistic.

Treatment: Treatment of CLA is often unsuccessful, but supportive care can be helpful. However, CLA abscesses must be treated to prevent ruptures and further contamination of other animals and environment. Parenteral antibiotics may be used in severe cases. Surgical drainage of the affected lymph nodes is recommended.

Prevention: The prevention of CLA can be achieved through strict biosecurity measures, immediate isolation of the affected animals from the flock. Surgical procedures such as castration, shearing or mass vaccination should be carried out through aseptic means and affected premises should be disinfected thoroughly.

3.4 Contagious caprine pleuro-pneumonia (CCPP)

Contagious caprine pleuro-pneumonia (CCPP) is a highly contagious and rapidly spreading mycoplasmal disease that affects a vast majority of goat's population, which is characterized by severe respiratory distress associated with sero-mucoid nasal discharge, dyspnea, coughing, pyrexia and general malaise.

Transmission: Main route of transmission occurs through inhalation of infected aerosol. Airborne transmission can result in distant spread [12]. Transmission by direct contact is also reported [13]. Infected objects, vectors, fomites and animal products are yet to be known in transmission role [14].

Etiology: Contagious caprine pleuro-pneumonia is a highly fatal disease that is caused by *Mycoplasma capricolum capripneumoniae* or Mccp (previously *Mycoplama biotype F38*), in Africa, Asia and the Middle East. Morbidity is often 100% and mortality may reach 80%.

Clinical signs: The disease is characterized by anorexia, dullness, depression, weakness and lethargy, pyrexia, weight loss and decreased production. Also have respiratory signs of bilateral nasal discharge (**Figure 4**, **Table 1**), dyspnea, tachypnea and coughing. Occasionally, the only sign seen is sudden death.

Figure 4.
Sign of bilateral nasal discharge in CCPP. By author.

Diagnosis: The simplest and quickest procedure in field diagnosis is the detection of antibodies by Latex agglutination (LAT) as is easy to run and has a long shelf life. Other diagnosis include growth inhibition disc tests (GI), direct and indirect fluorescent antibody tests, complement fixation test (CFT), indirect hemaglutination test, ELISA and PCR. Isolation of *M. capricolum capripneumonia* from clinical samples is the only way to definitively diagnose the infection but is not normally performed as it is difficult and time consuming.

Treatment: Macrolides, tetracycline and quinolones are very active against *M. capricolum capripneumonia*. Antibiotics like tylosin at 1 ml/10 kg and enrofluxacin at 1 ml/20 kg body weight can be helpful in the treatment of CCPP.

Prevention: ***V***accination has been an important aspect of CCPP prevention in a country where it is prevalent. Quarantine of affected animals and strict biosecurity measures for the introduction of new animals is necessary to reduce transmission and losses due to CCPP.

3.5 Dermatophilosis

Detmatophilosis is contagious bacterial disease of skin that affects sheep and goats. It is an infection affecting multiple species of animals world-wide, most common in young or immunosuppressed animals or in animals that are chronically exposed to wet conditions.

Transmission: Dermatophilosis is believed to be spread by direct contact between animals, through contaminated environments or possibly through biting insects.

Etiology: The disease is caused by a dimorphic bacterium, *Dermatophilus congolensis* that has two characteristic morphologic forms: filamentous hyphae and motile zoospores. Is a gram positive, non-acid fast, facultative anaerobic actinomycete, which is the only currently accepted species in the genus but, a variety of strains can be present within a group of animals during an outbreak [15].

Clinical signs: In severe generalized dermatophilosis, there is often loss of condition and motion, scab formation on the lips, muzzle, nose, ears (**Figure 5**, **Table 1**), feet and scrotom which if severely affected make prehension difficult. The scabs can become detached and reveal a yellow, creamy or hemorrhagic exudate. Allopecia can occur if the scabs are rubbed off. There is tufted papules and crusts that resembles paintbrushes. Concurrent infection with orf virus and other stress factors like malnutrition, pregnancy and lactation exacerbate the disease [16]. Most infections are mild

Figure 5.
Scab formation on the lips, muzzle and nose. By author.

thus render susceptible animal with normal functioning immune system spontaneously recover in time.

Diagnosis: Clinical and cytological examinations of fresh lesions are suggestive of the disease. A definitive diagnosis is made by demonstration of the organism in cytological preparations, isolation on culture and/or via skin biopsy. Indirect fluorescent antibody technique and a single dilution ELISA test have been developed for large serologic and epidemiologic surveys.

Treatment: The causal organism is susceptible to a wide range of antimicrobials. High doses of penicillin-streptomycin are effective in severely affected animals, if administered in early stage of the disease. Heavy doses of long acting tetra cline (20 mg/kg) may be used and topical application of lime sulfur is a cost-effective adjuvant to antibacterial therapy. Insect repellent can be use externally to control biting insects.

Prevention: Isolation and culling of clinically affected animals can be helpful in preventing the disease. Ectoparasites control is a method used in breaking the infective cycle of the parasite. Keeping susceptible animals dry and frequent checking of the zinc sulphate and copper sulphate level in feeds have been found useful in reducing the spread and incidence of the disease.

3.6 Mastitis

Mastitis is an inflammation of mammary gland due to physical injury, stress, bacterial or viral infections. It can either be clinical or subclinical. It is characterized clinically by clots or serum formation in the milk, swollen udder (**Figure 6**, **Table 1**), hot and tender to touch. Sub clinically, can be detected using California Mastitis Test (CMT), milk culture or Somatic Cell Count (SCC).

Transmission: In goats, both vertical and horizontal transmissions are likely to occur. But vertical transmission presents very low occurrence. The introduction of mastitis is favored mainly by the factors that intervene in the horizontal transmission of pathogen. The pathogens can be eliminated by milk, feces, urine and oronasal secretions. The hands of the milker, milking equipment, vectors and fomites as a general way. The most often entry is via the galatogenic route [17]. All animals are susceptible, increasing the predisposition mainly according to age and number of lactations [18].

Etiology: The disease has a multiple etiolo gy but *Staphylococcus aureus* and *Streptococcus agalactiae* are the commonest bacteria isolated from cases of mastitis in small

Figure 6.
Swollen udder in mastitic goat. By author.

ruminants. Other bacteria identified include *Corynebacterium pyogenes*, *Klebsiella spp*, *Mycobacterium spp* and *Brucella spp* [16].

Clinical signs: The clinical manifestations of acute mastitis include edema, elevated fever above 105^0 F, increased pulse rate, loss of appetite, depression, apathy, dyspnea, swelling and redness of the mammary gland, enlargement of the retro-mammary lymph nodes and lethargic movement are observed. Agalactia or lack of milk and hard lumps are common features of chronic mastitis. Claudication is a common sign in which small ruminants limps in order not to tamper with the inflamed mammary gland [19]. However, in subclinical mastitis, there is no evidence of clinical signs, but alterations in milk composition can occur and positive respond to CMT or other suggestive tests [20].

Diagnosis: History and clinical features are suggestive for tentative diagnosis. Microbiological culture can be reliable to determine the presence of organism in milk sample; California Mastitis Test (CMT) and somatic cell count (SCC) are commonest tests for mastitis. Other tests like multiplex-PCR and Enzyme-Linked Immuno Sorbent Assay (ELISA) are important techniques used in the diagnosis of mastitis.

Treatment: Glucocorticoids is recommended in the early course of disease, antibiotics like penicillin streptomycin (penstrep) at 200 mg/ml for 3–5 consecutive days is effective, oxytetracycline, benzylpenicillin, cloxacillin, amoxicillin,, ampicillin, or erythromycin have been recommended to treat mastitis. Some strains of *S. aureus* have found to be resistant to penicillin, hence drug sensitivity test is recommended before the use of such drugs on the treatment of mastitis. Topical application of antibiotic cream can be helpful.

Prevention: Proper milking practices, good hygiene for milking utensils and culling persistent infectors can help in reducing the incidence of the disease. Kidding pens and Bedding should be disinfected daily to avoid growth of pathogenic bacteria. Abscess draining and proper wound dressing can be carried out regularly. The hygienic-sanitary management aimed at preventing mastitis involves a number of factors including the choice of antimicrobial, microorganism susceptibility, duration of treatment, dosage employed, and the animal's immune status [21].

3.7 Foot rot

Foot rot is a contagious disease of the hooves in goats and sheep, characterized by ulceration and necrosis of the sensitive laminae of the foot (**Figure 7**, **Table 1**) and lameness. This disease is prevalent in the Southern region of the United States due to wetness and humidity of the environment.

Figure 7.
Ulceration and necrosis of laminae of foot in goat.

Transmission: Transmission is mainly enhanced by genetics, stocking rate and environmental factors. The disease can be spread from infected animal to non-infected susceptible animals (direct transmission). Incidence of overgrown hooves can predispose animals to foot rot. During the rainy season, infected animals can contaminate the soil and muddy pens which can enhance disease transmission to other animals If not treated; sick animals can become permanently infected [22]. The organism can also be transported to the soil by visitor's shoes.

Etiology: Foot rot is disease caused by a large Gram-negative rod-shaped bacterium, *Fusobacterium necrophorum* and *Dichelobacter nodosus* which are mostly common in contaminated soil.

Clinical signs: Foot rot results in lameness, inappetence, loss of weight, and necrotic lesions in the interdigital space with foul smelling of the foot, there is elevated temperature and reduced production performance, lethargy, grazing on knees and abnormal gait. This condition may result increase in production losses, cost of treatment and prevention. Affected animals will lose value due to the infection [23]. The disease is very difficult to eradicate when it affects a herd/flock.

Diagnosis: The first signs of hoof rot are limping, holding limbs above the ground, grazing on knees, and abnormal gait, should be sufficient for diagnosis. If laboratory confirmation is required, submit smears and swabs of interdigital exudate and necrotic tissue from multiple animals for bacteriology.

Treatment: Systemic administration of antibiotics (penicillin streptomycin or oxytetracycline) and dry underfoot conditions usually resolve even severe lameness after a few days without the need to pare away dead horn. To curate in-between hooves with potassium per manganite and topical application of aerosol sprays of cetrimide or oxytetracycline may be helpful. Foot bathing in formalin or zinc sulphate (with surfactant) is another success achievable option.

Prevention: Quarantine all newly purchased animals before introducing in to the flock, isolate affected animals and give a deserving treatment, keep barn dry and clean to avoid contamination, Provide good drainage to areas of pastures and paddock, trim hooves regularly, supplement trace minerals and vitamins and give adequate nutrition.

4. Fungal disease of goats

4.1 Candidiasis

Candidiasis is a mucocutaneous fungal disease caused by a yeast-like fungus. It is a normal inhabitant of gastro intestinal tract, nasopharynx and outer genitalia of different species of animals.

Etiology: Candidiasis is caused by a yeast-like candida specie most commonly *Candida albicans* that usually affects immunocompromized animals and opportunistic in causing diseases. The disease is distributed worldwide in a different spp. of animals [24].

Clinical signs: Signs noticed are defined patch of red itchy skin, pustules and scabs (**Figure 8**, **Table 1**). There is a local overgrowth of candida spp. on the tongue and mucosa of the mouth that appears as white plaques. Anorexia, dehydration, watery diarrhea, loss of weight and sometime death. Affected kids may develop listlessness, inappettance and stunted growth.

Diagnosis: Diagnosis can be made by microscopic examination of scrapings or biopsy specimens from mucocutaneous lesions. The fungus can be seen visibly on

Figure 8.
Area of pustules and scabs in goats with candidiasis. By author.

staining with Wrights, methylene or Gram stain techniques. It can also be confirmed on culture of a sample in blood or tissue agar.

Treatment: Antifungal like amphotericin B or nystatin ointment can be effective when use topically, 1% iodine solution may also be used in the treatment of cutaneous candidiasis.

4.2 Cryptococcosis

Cryptococcosis is a dimorphic potential fungal disease of mainly the lung and brain that is distributed worldwide and affects immunocompromised animals especially goats and sheep causing pneumonia and or meningitis [25].

Etiology: At least 322 species of the genus Cryptococcus (*Tremellales, Agaricomycotina*) have been described [26]. However, only *Cryptococcus neoformans* (*var. neoformans* and *var.grubii*) and *C. gattii* have been described as causing disease in humans and domestic animals [27]. The pathogenic species of Cryptococcus are the only species of the order Tremellales able to grow well at temperatures >30°C, and their capacity to grow at 37°C is one of their main virulence factors [28].

Clinical signs: In cryptococcosis signs observed are; pyrexia, paraplegia, depression, severe dyspnea due to the obstruction of the nostrils, swelling of the nasal region, purulent nasal discharge, with abundant granulation tissue and hemorrhagic exudate in the nostrils [29]. Goats may have severe respiratory disease, including cough, anorexia, fever and severe weight loss [27]. Neurologic signs may also be observed in goats [30] and or meningitis (**Figure 9**, **Table 1**). The infection is sub-acute to chronic, with a clinical course of 2–6 week in goats and sheep [29].

Diagnosis: Diagnosis. A definitive diagnosis can be achieved by cytologic evaluation of cerebrospinal fluid, skin and nasal exudates or isolation of *C. neoformans* from blood or body fluids such as CSF. Cryptococcal antigen latex agglutination serology (CALAS) can be performed on serum or body fluids but only provides presumptive evidence [31]. Gram stain is also useful.

Treatment: Prompt anti-fungal treatment such as Amphotericin B plus flucytosine, fluconazole, itraconazole or ketoconazole was found effective in the treatment of Cryptococcus in goats especially when treatment with antibiotics did not give any result. Success with oral fluconazole (5 mg/Kg/day orally for 6 months) was established in a goat with abdominal wall infection with *C. gatti* [32].

Figure 9.
A sign of cryptococcal meningitis in goat. By author.

Prevention: It is difficult to prevent exposure to Cryptococcus in goats, since it is commonly found in the environment. Avoidance and environmental control of bird droppings (especially pigeons) are important [33]. Good hygiene and environmental sanitation is paramount in the prevention of the Cryptococcus.

4.3 Ringworm

Ringworm is a skin lesion usually circular and hairless, caused by a fungal infection of the hair follicle and outer layer of skin. Ringworm is a zoonotic disease. Sheep and goats develop crusty, scaly, circular patches that may or may not be pruritic (itchy).

Transmission: It is transmitted by close contact between animals or via animals contracting infective spores in the environment or by direct or indirect contact with contaminated equipment or environment.

Etiology: Ringworm is sometime called wool fungus, which is typically from the *Trichophyton* or *Mycosporum* genera. Ringworm is highly contagious and zoonotic in nature.

Clinical Signs: The primary signs observed are alopecia, scaling, crusting and poor growth. Sheep and goats develop moist and reddened skin, but later gray, scaly and dry, circular patches (**Figure 10**, **Table 1**) which is due to coalesced lesions that may or may not be pruritic (itchy). In more severely affected animals, lesions become confluent to produce an extensive areas of infection. Sheep and goats used for

Figure 10.
Gray scaly dried circular area consumed by ringworm. By author.

exhibition are at a much higher risk of contracting ringworm due to shearing practices, which cause exposure of the skin and the spread of fungal spores [34].

Diagnosis: Diagnosis is typically made by visual examination and/or microscopic examination of biopsy of lesions, hair or skin scrapings. A definitive diagnosis and identification of the organism is made by a fungal culture.

Treatment: Treatments may not shorten the time to complete healing of lesions. Treatment with ketoconazole is found effective. Topical application of charmil gel can be helpful. The use of imidazole spray may stop progression of lesions and lower the spread to other animals.

Prevention: It is important to isolate infected animals so as not to spread ringworm to the rest of the flock or herd. Minimize mixing of animals in pre-confinement periods. Not only is it important to treat the animal, it is important to disinfect pens and anything with which the infected sheep or goat may have been in contact [34]. Thorough hand washing is also recommended after treating the animals.

4.4 Aspergillosis

Aspergillus spp. may cause infections in a variety of domestic animals. They are saprobes that are widely distributed in nature. Spread occurs via aerosols of spores present in soil, decaying vegetation, and occasionally animal tissues [35], a specialized hyphal structure of some fungi that produce conidia (asexually produced spores borne externally to the cells), can be observed in highly oxygenated tissues, such as those of the respiratory system [36].

Etiology: Aspergillosis is caused by several species of aspergillus, and there are more than 300 species of Aspergillus [37]. *A. fumigatus* is known to be directly associated with infection. Other spps like *A. niger, A. flavus, A. terreus,* and *A. nidulans* are opportunistic pathogens that are being recognized commonly with the use of molecular techniques.

Clinical signs: In ruminants, signs include moist cough, nasal discharge, pyrexia and shallow respiration. Pulmonary aspergillosis in sheep and goats is characterized clinically by anorexia, dyspnea, apathy, cough and nasal discharge [38]. The lungs are mottled, firm and heavy. There may be loss of condition associated with necrosis of the nasal mucosa in goats with nasal form of aspergillosis which may result in severe dyspnea (**Figure 11**, **Table 1**).

Diagnosis: Aspergillosis can be confirmed by immunohistochemical, molecular and culture-based diagnostic methods. Macroscopic and histologic lesions can be used

Figure 11.
Nasal and cutaneous aspergillosis in goat. By author.

as presumptive diagnosis. There is another alternative diagnostic approach which involves the use of pan-fungal PCR on animal tissues [39]. Immunodiffusion, complement fixation, and ELISA can be used to detect antibodies against *Aspergillus spp* [40].

Treatment and prevention: Antifungal agents are currently unlicensed, but management of the disease usually relies on preventative measures such as ensuring clean bedding, good hygiene and good husbandry.

5. Parasitic diseases of goats

Parasites commonly found in goats can be divided into two general categories: Internal (Endo) and External (Ecto) parasites:

5.1 Endo parasites of goats

Endo parasites are worms that live in the body or inside an organ and there are multiple types. The most common internal parasites in goats are: Nematodes (roundworms) e.g. lung worms (*Dictyocaulus spp*. or *Muellerius capillaris*), Tapeworms, for example, moniezia, Liver flukes, for example, *Fasciola hepatica*, and intestinal parasites like Coccidia, for example, *Eimeria* or *Isospora* and Cryptosporidia. Parasites grow and reproduce in certain environments. Goats that live in those environments are at high risk of becoming infested [41].

Clinical signs: The clinical signs of endoparasitism in goats include: reduced weight gain, decreased milk yield, Diarrhea, Rough hair coat (**Figure 12**, **Table 1**), loss of condition, Weakness, Anemia, Fever, hyperpnea, Coughing and Bottle jaw.

Diagnosis: Endo parasite of goats can be diagnosed mainly based on laboratory tests. The commonly used laboratory tests for the diagnosis of endo parasitic diseases include blood packed cell volume, etiological examination, which involves the detecting of the parasitic larvae or eggs from stool, blood, nasal secretions as well as tissue of the animals, serological assay such as Enzyme linked immunosorbent assay, indirect hemagglutination test or fluorescence immunoassay and molecular diagnostic techniques such as polymerase chain reaction (PCR) or DNA sequencing.

Figure 12.
Diarrhea and rough haircoat in goat affected by internal parasite. By author.

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Treatment: Benzimidazoles (oxfendazole, febantel, fenbendazole and albendazole) Macrocyclic lactones: Avermectins (ivermectin, doramectin and eprinomectin) Milbemycins Cholinergic agonists: Imidazothiazoles (levamisole) Tetrahydropyrimidines (pyrantel and morantel) are found effective for internal parasite. However, only morantel, thiabendazole, fenbendazole, albendazole and phenothiazine are approved for goats [42]. Dewormer resistance occurs when there is less than 95% reduction in fecal egg count 14 days after administration. Resistance has risen due to anthelmintics being used often, rotated too frequently or under dosed.

Prevention: The best prevention is to alternate livestock species grazing, avoiding overcrowding of pens or premises, genetic improvement and pasture rotation. Balanced nutrition is very important to keep animals healthy and help them develop appropriate resistance to external pathogens, especially for dams before and after lambing/kidding. Also practice the use of effective dewormers.

5.2 Ectoparasite of goats

Ectoparasites feed on body tissues like skin, hair or blood, and they include fleas, flies, lice, mites, nose botfly and ticks. The wounds and skin irritation produced by these parasites result in discomfort and irritation to the animals. Parasites can transmit diseases from sick to healthy animals, which can reduce weight gains and milk production.

Clinical signs: Mites infect the head, legs, body or tail region causing the skin to become crusted and cause loss of hair and wool (**Figure 13**, **Table 1**). The infected area itches and the animal scratches. The host does not feed well. The infections cause skin damage to a goat. Lice, flea and flies are found where animals are kept in overcrowded confined environment and cause irritation of the skin, anemia and damage to the skin. It causes loss of weight and condition to the host. The can transfer from one animal to another through close contact. Ticks are very important parasites that can harm its host by bites resulting in anemia, weakness and debility. Ticks can be classified according to groups; one-host, two-host and three-host ticks. Ticks that are known to infest goats are those belonging to three-host tick as they parasitize three different hosts in their life cycle that make their control very difficult. Ticks also spread diseases (tick borne diseases) that are so fatal to its host. Nose botfly infests the nostril of goats causing irritation, sneezing, shaking of the head, nasal discharge, respiratory distress, loss of appetite and grinding of the teeth.

Figure 13.
Loss of hair caused by ectoparasite by author.

Diagnosis: Identification of ectoparasites can prove difficult because detailed clinical examination can fail to confirm the presence of some ectoparasites. It may be necessary to take skin stub samples to investigate whether arthropods such as mites are in residence. Ticks, flea, flies and biting lice usually can be seen with the naked eye. The presence of mites can be confirmed by examining mites, eggs and fecal pellets in skin scrapings under the stereoscopic microscope.

Treatment: Mites and lice are controlled by washing the infected area, spraying or dipping the animal with a suitable treatment. If an animal has only a few ticks these can be carefully pulled off making sure the mouth parts of the tick are removed. Dipping is very effective if large numbers of livestock need to be treated. Ivermetin injection and pour on are also effective in the treatment of ectoparasite, but accurate dose must be maintained.

Prevention: Monitoring program should be exercise to insure early identification. Sanitation and regular cleaning of facilities using appropriate detergent and disinfectant is helpful in the prevention of ectoparasite. Eliminate areas where external parasites can breed and develop (e.g. elimination of standing water reservoirs decreases mosquito levels). The use of Insecticides and fly predators may be necessary.

6. Protozoa/Rickettsial diseases of goats

6.1 Babesiosis

Babesiosis is an infectious tickborne, obligate, intraerythrocytic protozoan parasites from the phylum *Apicomplexa*, order *Piroplasmida* affecting a wild and domestic animals which include cattle, sheep and ggoats. It is typically fatal disease that is characterized by hemoglobinuria, fever, icterus and intravascular hemolysis resulting to anemia. Variety of animals. Susceptible animals may suffer high rate of mortality but recovered animals that are latently infected has an immunity for a certain period of time. It is transmitted transovarially by ticks. By the ingestion of the parasite, the female tick becomes infected during engorgement, upon drops off of the babesial agents on the host, it reproduce within the tick's tissues which is incorperated within the embryo of the developing ticks resulting to the transmission of the disease to the new hosts by feding of ensuing tick larvae, nymphs, or adults [43].

Transmission: Babesiosis is transmitted by ticks *Boophilus*, *Hemaphysalis*, *Hyalomma, Dermaentor* and *Ixodus spp* are the vetor in the transmission of *Babesia* of different species. It is transmitted in both transovarially and transstadially. *Babesia spp* affecting goats and sheep may be maintained in non-susceptible hosts such as wild animals [16].

Etiology: Although small ruminants can be infected by several species of *Babesia*, the two most important species associated with Babesiosis in goats are *B. ovis* and *B. motasi*, transmitted by *Rhipicephalus bursa* and *Haemaphysalis spp,* respectively. Infection is of importance in the Middle East, southern Europe, and some African and Asian countries.

Clinical signs: *B. motasi* can cause an acute or chronic Babesiosis in goats, generally runs a course of 1 week or less. In acute infection, the first clinical signs are anorexia, lethargy, depression, and fever (frequently ≥41°C]), which persist throughout, and these are accompanied later by inappetence, anemia and jaundice (**Figure 14**, **Table 1**), hemoglobinemia and hemoglobinuria occur in the final stages. Chronic infection is manifested by emaciation, coughing and edema. Many animals recover; however, some may die if not treated.

Figure 14.
Anemia and jaundice seen in Babesiosis. By author.

Diagnosis: History and clinical findings may provide a presumptive diagnosis of babesiosis. However, Giemsa-stained blood or organ smears by light microscopy is essential to confirm the diagnosis. The most commonly used tests are ELISA, PCR and a DNA probe, which can detect specific parasitemias at very low levels of infection [44].

Treatment and prevention: Babesiosis can be treated using diminazene aceturate (3-5 mg/kg), phenemidine diisethionate (8-13 mg/kg), imidocarb dipropionate (1-3 mg/kg), and amicarbalide diisethionate (5–10 mg/kg) [43, 44]. Supportive treatment such as blood transfusions (4liters of whole blood per 250 kg of body weight), fluids, hematinics, and prophylactic antibiotics are important [43]. The disease can be prevented by effective quarantine of the susceptible animals so as not allow the introduction of the vector ticks. The control of ticks by dipping or spraying animals at risk with recommended acaricides is paramount.

6.2 Coccidiosis

Coccidiosis is an enteric protozoan disease of goats caused by the genus *Eimeria*. Coccidia go through a complex life cycle in the intestinal cells of animals. Large number of eggs called oocysts are being produced in the intestine and passed in the feces. The intestinal cells can be damaged as a result of growth and multiplication of the coccidia in the intestinal epithelial cell thereby causing diarrhea and other signs of the disease.

Etiology: Coccidiosis in goats is caused by several species of *Eimeria*, but *E. arloingi* and *E. ninakohlyakimovae* are known to be pathogenic. All the goat *Eimeria spp* are considered host specific and do not transfer infection from goats to sheep. In most cases, concurrent coccidial and helminthic infections can occur especially in animals on extensive management system [45].

Clinical signs: In most cases, clinical coccidiosis occurs between 5 and 8 weeks of age. Most goat kids have subclinical infection. In acute or sub-acute infections, the usual signs are pasty feces, dirty tails, stary coat, loss of weight, dehydration and inappetence. More severe acute cases show mucoid or bloody diarrhea, possible tenesmus, dullness, anorexia, weakness and anemia. Severe problems lead to rapid onset of diarrhea, often with blood, tenesmus, and signs of abdominal pain, lethargy, recumbences, and death. In chronic infections, there is delayed puberty, debilitation, poor appetite, loss of weight and liver failure especially in milking goats.

Diagnosis: Diagnosis can be based on history, age of kids, clinical signs especially of severe diarrhea, fecal examination and postmortem findings. Acute coccidiosis can be diagnosed by direct examination of feces but in chronic coccidiosis that have very low oocysts number are seen in feces (**Figure 15**, **Table 1**), direct examination of feces may not be adequate [46].

Treatment and prevention: Sulfadimidine (sulfamethazine) injection (10–50 mg/kg) for five consecutive days is found effective. Vetcotrim bolus (10-30 m/kg Per Os once daily for 3 days) has a good result. Decoquinate (Deccox, 0.5 mg/kg) and Monensin 13-20grams/ton of feed can be used in non-lactating goats. Diclazuril (1 mg/kg, PO, once) and toltrazuril (20 mg/kg, PO, once) have been used successfully; doses may need to be repeated. A metabolite of toltrazuril, ponazuril (10 mg/kg, PO, once) reduced oocyst counts when used experimentally in goat kids. Ensure good nutrition program, Improved good hygiene in the house, minimize predisposing factors, avoid crowded pens and pastures, Feed and water troughs should be raised off the ground to prevent fecal contamination.

6.3 Theileriosis

Theileriosis is caused by *Theileria spp*. a genus comprising tick-borne transmitted protozoa of the family *Theileridae*, order *Piroplasmida*, subclass *Piroplasmia*, Phylum *Apicomplexa*. *Theileria species* affect domestic and wild ruminants, especially in Africa, Europe, Australia, and Asia [47].

Etiology: Theileriosis in sheep and goats is usually caused by *T. lestoquardi* (formerly *T. hirci), T. uilenbergi* or *T. luwenshuni.* Morbidity and mortality rates of up to 65% *(T. luwenshuni*) and 75% (*T. uilenbergi*) have been seen in susceptible animals introduced into endemic areas. Affected animals show sustained fever and anemia.

Clinical signs: The clinical signs of theileriosis in goats infected with *T. lestoquardi* are similar to other forms of theileriosis, which include anorexia, slight oculo-nasal discharges, fever, salivation, enlargement of superficial lymphnodes, weight loss, respiratory distress (**Figure 16**, **Table 1**), edema of the lungs, anemia, icterus and diarrhea, death may occur due to asphyxia. Abortions may also be seen. In most cases, experimental infection of sheep and goats with *T. annulata* resulted in only mild to moderate clinical signs of fever and lymphadenopathy [48].

Diagnosis: Theileriosis can be diagnosed on Giemsa-stained thin smears from blood or lymph node biopsies. At necropsy, impression smears can also be used to detect schizonts from many internal organs of infected animals such as the liver, spleen, lymph nodes and lungs. Other diagnostics tools like antigen- specific ELISAs and PCR are often used in diagnosis and can identify *Theileria* in the blood of both

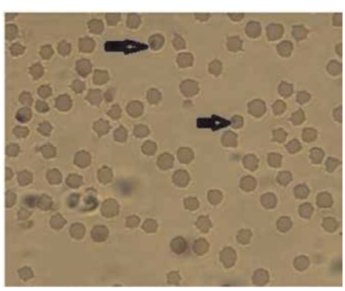

Figure 15.
Slide showing coccidiosis in goats.

Figure 16.
Respiratory distress and loss of weight by author.

carriers and clinical cases. Some tests can differentiate the species of *Theileria*, while others are specific for the genus [48].

Treatment and prevention: Infected goats can be treated with antiparasitic drugs like Buparvaquone (2.5 mg/kg) is very effective in the early stage of the disease. Use of Oxytetracycline 10 mg/kg is found helpful. Antidiuretics and anti-inflammatory drugs may also be used when there is evidence of pulmonary edema. In advanced stage of the disease, treatment is less effective especially where there is extensive destruction of lymphoid and hematopoietic tissues [49]. Control of ticks by spraying or dipping of animals with acaracides is the most successful method used for the prevention of theileriosis, but this needs to be applied at regular intervals to be effective. Pyrethroid compounds are often used where animals are exposed to tickborne diseases.

6.4 Cowdriosis

Cowdriosis (Heartwater) is regarded as the most important infectious, noncontagious, tickborne rickettsial disease of ruminants that is clinically characterized by diarrhea, fever, hydropericardium, hydrothorax and edema of lung and brain. The disease is seen only in areas infested by ticks of the genus *Amblyomma*.

Etiology and transmission: The disease is caused by a pleomorphic ricketssia *Ehrlichia ruminantium* which is an obligate intracellular parasite previously known as *Cowdria ruminantium.*. Under natural conditions, *E ruminantium* is transmitted by *Amblyomma ticks.* Transmission occur mainly transstadially, but transovarial transmission rarely occurs.

Clinical signs: The incubation period of Heartwater in goats and sheep is 1–5 weeks and the course of acute disease takes 3–6 days. The clinical signs are dramatic in the peracute and acute forms. In peracute cases, animals may die suddenly without any premonitory signs; other animals developed dyspnea and intense convulsion. In the acute form, there is pale mucous membrane, anorexia and depression (**Figure 17**, **Table 1**). Other signs of hyperesthesia, nystagmus, chewing movements and a high-stepping stiff gait may be noticed. Terminally, prostration with bouts of opisthotonus, circling or galloping movement, and stiffening of the limbs, intermittent diarhea and convulsions are also seen. Subacute form is less pronounced, but there may be prolonged fever, mild incoordination and coughing. Nervous signs are inconsistent.

Figure 17.
Anorexia and depression by author.

Diagnosis: presumptive diagnosis is based on clinical, epidemiological and pathological features; *E.ruminantium* colonies can be identifiable in the brain or intima of blood vessels on staining with Giemsa or methylene blue; Molecular methods like real-time PCR has an advantage of being less time consuming and free of cross contamination; Serological tests such as indirect fluorescent antibody tests, enzyme linked immunosorbent assays (ELISA) and Western blot are used for definitive diagnosis.

Treatment and prevention: Sulfonamides and tetracyclines can be used in the early stage of the disease, when it advances the prognosis may be poor. Oxytetracycline 20%long acting at 10 mg/kg/day may be helpful or doxycycline at 2 mg/kg/day will be effective, if administered early in the course of heartwater infection. Diazepam may be required to control convulsions. Dexamethasone injection will be serve as supportive care, although the rationale behind its effectiveness is much more controversial. Control of tick infestation is a good preventive measure in some instances but may be difficult and expensive to maintain in others. In areas of endemicity, the use of dips against ticks of domestic animals is highly recommended. Affected animals must be confined in a quiet and cool areas that is devoid of any other disturbances because, any stimulation can cause a convulsion and abrupt death. Vaccination can be helpful in the prevention and control of cowdriosis.

6.5 Anaplasmosis

Anaplasmosis is a tickborne obligate intraerythrocytic bacteria of the order *Rickettsiales*, family *Anaplasmataceae*, genus *Anaplasma*, that infect red blood cells, causing fever and anemia.

Etiology and transmission: *Anaplasma ovis* may cause mild to severe disease in sheep, goats and deer which is typically transmitted by ticks or biting flies. Up to 17 different tick vector species (including *Dermacentor*, *Rhipicephalus*, *Ixodes*, Hyalomma, and *Argas*) have been reported to transmit Anaplasma spp. Iatrogenic transmission can occur when instruments are re-used without proper sanitation, including instruments used for dehorning, ear tagging, castrating, and vaccinating. In utero transmission has also been reported.

Clinical signs: Anaplasmosis is usually subclinical or less severe in young animals, it is severe and often fatal in older. Anaplasmosis is characterized by progressive anemia due to extravascular destruction of erythrocytes. Macrocytic anemia with

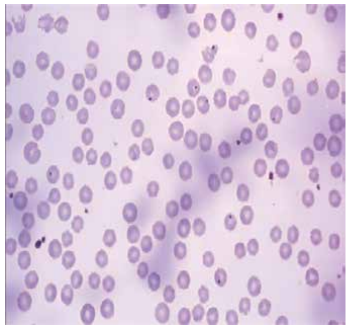

Figure 18.
Slide showing anaplsma spp.

circulating reticulocytes may be present late in the disease [50]. Animals with peracute infections succumb within a few hours of the onset of clinical signs. Acutely infected animals lose condition rapidly. Incoordination, loss of appetite, dyspnea, and a rapid pulse are usually evident in the late stages. The urine may be brown, but, contrary to babesiosis, with no hemoglobinuria. Mucous membranes appear pale and yellowish. There is abortion, hematologic parameters gradually return to normal after convalescence.

Diagnosis: Diagnosis based on clinical features, hematological changes, blood smears, and serologic testing. Microscopic examination of Giemsa-stained thin and thick blood films (**Figure 18**, **Table 1**) is critical to distinguish anaplasmosis from babesiosis and other conditions that result in anemia and jaundice, such as leptospirosis and theileriosis. Serological tests like ELISA, complement fixation, or card agglutination tests has been used to identify chronically infected carriers but with doubtful degree of accuracy. Nucleic acid-based detection methods can be used, but carrier level of infections may not be detected [50].

Treatment and prevention: Oxytetracycline has been reported to reduce severity of the disease. The use of imidocarb has been shown to be very effective in the treatment of anaplasmosis. Good sanitary methods such as cleaning of stalls/pens regularly can help to reduce contamination. Avoid re-using of needles and disinfect medical equipments when use. Treatment with an effective acaricides to kill ticks may help to reduce the incidence of anaplasmosis.

7. Viral diseases of goats

7.1 Peste des petits ruminants (goat plaque)

Peste des petits ruminants is an acute, highly contagious transboundry viral disease primarily affecting goats and less commonly in sheep associated with high morbidity and mortality caused by PPR virus of the genus *morbilliirus* and family *paramoviridae* that closely resembles rinderpest virus.

Etiology and transmission: is caused by a PPR virus of the genus *Morbillivirus* of the family *paramoviridae* (sub family *Paramixovirinae*) under the order *Mononegavirales* which is related to but distinct from Rinderpest virus of cattle. The PPRV is genetically grouped into four genotypes (lineages) [51], based on the Fusion (F) and Nucleoprotein (N) gene sequences. Lineages I and II circulate mainly in West

Africa, lineage III is mostly in Eastern part of Africa, while lineage IV is generally found in Asia, but has now spread to the African continent and become the most prevalent of all the lineages [52]. The disease is transmitted by infected aerosols in situation of close contact of animals and confinement seems to favor outreaks. Fomites like bedding, feed and water troughs also help in the transmission of PPR.

Clinical signs: In acute form, goats typically display an abrupt rise in temperature to 40–41°C. Within a few days, infected animals develop oculo-nasal discharges (**Figure 19**, **Table 1**), thirst, anorexia, depression and leukopenia [3].

Conjunctival mucous membranes may be congested, followed by serous and mucopurulent exudates. Affected animal develop necrotic oral erosions that produce a fetid smell. There is profuse diarrhea which develops within 2 to 3 days and is accompanied by abdominal pain, tachypnea, loss of weight and severe dehydration. There may be abortion 5 to 10 days after the onset of fever. The incSubation period is usually 4-5 days.

Diagnosis: History and clinical features give a presumptive diagnosis in endemic regions. The virus can also be detected in acute cases from various swabs and blood samples, using PCR and ELISA.

Treatment and prevention: PPRV infection has no specific treatment. Mortality can be reduced by supportive care, including the administration of Antibiotics such as chloramphenicol, penicillin, and streptomycin, inflammatory agents, as well as nutritional support. State and federal veterinarians should be notified if PPRV is suspected. Sheep and goats can be protected against PPR by immunization with rinderpest vaccines or by the simultaneous administration of PPR hyper immune bovine serum and virulent PPRV [52]. Premises should be decontaminated, and the area quarantined. Movement restrictions can also aid in the prevention of the disease.

7.2 Goat pox

The sheep pox virus (SPV) and goatpox virus (GPV) are serious acute, often fatal febrile contagious viral skin diseases of sheep and goats caused by the members of the *Poxviridae*, genus *Capripoxvirus* which is characterized by widespread skin eruptions. They are believed to be closely related antigenically and physicochemically, which are able to infect both sheep and goats.

Etiology and transmission: Sheep pox and goat pox is caused by the infection of sheep pox virus (SPV) or goat pox virus (GPV), closely related members of the genus Capripox virus in the family *Poxviridae*. SPV is mainly thought to affect sheep and

Figure 19.
Purulent oculo-nasal discharges. By author.

GPV primarily to affect goats, but some isolates can cause mild to serious disease in both species. (CFSPH). Transmission is by direct contact, while indirect transmission by contaminated implements, vehicles or products such as litter or fodder. Indirect transmission by mechanical vectors like insects is also possible. Transmission by inhalation is important. SPV and GPV are shed in saliva, nasal and conjunctival secretions.

Clinical signs: Sheep pox and goat pox appear similar, with clinical signs that typically include: Fever, red spots that become blisters (**Figure 20**, **Table 1**) on the muzzle, eyelids, ears, udder or in severe cases all over the body [53]. Lesions can develop internally causing breathing difficulties, depression, lethargy, reluctant to feed, oculo-nasal discharges or swollen eyelids and enlarged superficial lymphnode.

Diagnosis: *Capripoxviruses*, their antigens and nucleic acids can be detected in skin lesions (e.g. biopsies, scrapings, vesicular fluid, scabs); oral, nasal and ocular secretions; blood; lymph node aspirates; and tissue samples from external or internal lesions collected at necropsy PCR can identify viral RNA directly in tissue samples, blood and secretions. Other tests to detect capripoxvirus antigens include enzyme-linked immunosorbent assays (ELISAs), immunostaining methods and agar gel immunodiffusion (AGID).

Treatment and prevention: There is no specific treatment for sheep pox or goat pox, but supportive treatment may reduce morbidity and other complications. Newly introduced animals should be quarantined. Other biosecurity measures, such as prevention of contact with other herds and disinfection of fomites are also helpful. Stringent cleaning and disinfection of farms and equipment, animal and vehicle movement controls within infected areas, Vaccination may be considered in the area where the disease is endemic.

7.3 Caprine arthritis encephalitis (CAE)

Is a viral disease of goats caused by a lentivirus called caprine arthritis encephalitis virus, which is an enveloped, single-stranded RNA in the family *Retroviridae*. The disease is found worldwide [54]. There are several genetically distinct isolates of the virus that differ in virulence.

Etiology and transmission: Caprine arthritis encephalitis virus is an enveloped, single-stranded RNA *lentivirus* in the family *Retroviridae*. There are several genetically distinct isolates of the virus that differ in virulence. Cross-species transmission is possible via feeding of colostrum or milk from infected goats. Therefore, the ovine and caprine lentiviruses are commonly referred to as small ruminant lentiviruses [55].

Figure 20.
Clinical manifestation of capripoxvirus. By author.

Clinical signs: the most common sign is polysynovitis-arthritis which includes joint swelling (**Figure 21**, **Table 1**) and lameness of varying severity. There is Stiffness, abnormal gait and posture, loss of weight and depression. In goats which develop the neurological form of the disease, show ataxia, incoordination, hypertonia and hyperreflexia are also common. The goat has increased difficulty standing and eventually is unable to stand [56]. Lameness may be sudden.

Diagnosis: Based on history and clinical manifestations. Serologic tests like agar gel immunodiffusion test and ELISA are useful to determine herd CAEV status.

Treatment and prevention: There is no specific treatments currently exist, likewise there is no vaccine but supportive care is indicated. To prevent spread of the disease, infected animals are separated from non-infected goats, or culled [55]. Separating goat kids from infected goats, and feeding the kids with cow's milk, or pasteurized goat milk, will prevent infection [54]. Goats should also be quarantine and tested for CAE virus before introducing to the herd.

7.4 Contagious ecthyma (orf)

Orf is one of the most widespread highly infectious viral diseases of mostly small ruminants and sometimes other species, including wild animals. It occurs worldwide and characterized by scabby and pustular lesions on the muzzle, commissures of the lips and nostrils.

Etiology and transmission: is caused by Orf virus which is type species of the genus *Parapoxvirus* of subfamily *Chordopoxvirinae* of family *Poxviridae.* Natural transmission of disease occurs through direct or indirect contact with infected animals particularly with dried crusts that falls on the pastures during grazing.

Clinical signs: The primary lesion develops on the lips, muzzle and may extend to the mucosa of the oral cavity. Early in the infection, sores appear as blisters that develop into crusty scabs (**Figure 22**, **Table 1**). Lesions can sometimes be found on the feet and around the coronet, there is inappettance and loss of condition. During the course of the disease, there is presence of a nodules with red colorations in the center, a bluish white rings in the middle and peripheral erythematous. The lesions may progress to form papules and extends through vesicular and pustular stages to become encrusted. The Coalition of the numerous discrete lesions produces a large scab that result in the proliferation of dermal tissue that produces a verrucose mass beneath them [57].

Figure 21.
Joint swelling seen in CAE. By author.

Figure 22.
Crusty scab in Orf. By author.

Diagnosis: is based on clinical features and histopathology of skin lesions, transmission experiments and demonstration of a pox virus by electron microscopy of skin biopsies of infected skin.

Treatment and prevention: Antibiotics such as penicillin, chloramphenicol and10% Potassium permanganate solution is effective in case of lip lesions. In a situation complicated with stomatitis or enteritis, parenteral administration of antibiotics in conjunction with topical applications of salicylic acid ointment can give good result. Live vaccines should be used cautiously to avoid contaminating uninfected premises, and vaccinated animals should be separated from unprotected ones.

8. Metabolic and nutritional diseases of goats

8.1 Peripaturient hypocalemia (milk fever)

Parturient paresis is a non-febrile metabolism disturbance of pregnant and lactating ewes and does characterized by acute-onset of hypocalcemia, hyper excitability, circulatory collapse, flaccid paralysis, depression, recumbency, coma, and death.

Causes: Parturient paresis is as a result of decreased calcium intake on circumstance of high demand for calcium particularly during late gestation. This will result to low serum calcium concentration in pregnant animals with multiple fetuses. As fetuses mature and their bones mineralize, they require increasing amounts of calcium. Goats are required to mobilize stored calcium so as to increase calcium absorption, to meet up with the requirement. Failure to meet up with such calcium requirement especially during these periods put goats at significantly high risk of this condition.

Clinical signs: In early hypocalcemia, the most commonly noted clinical signs are lethargy and inappetence (**Figure 23**, **Table 1**), decreased body temperature, stiff gait, ataxia, salivation, depressed rumen motility, mild bloat or constipation, recumbency, weakened uterine contraction and if untreated, death.

Diagnosis: A working diagnosis is based on history and clinical signs. In outbreaks occurring before parturition, pregnancy toxemia is the main differential diagnosis [58]. Diagnosis can be confirmed by testing serum calcium concentration before treatment. Urine ketone or serum beta-hydroxybutyrate concentrations should always be evaluated at the same time. Tentatively, diagnosis of acute hypocalcemia is aided by a rapid response to slow IV administration of calcium.

Figure 23.
Lethargy and inappettance by author.

Treatment and prevention: Treatment is by IV administration of calcium borogluconate 50–150 milliliters of a 23% solution, which will elicit rapid response. Oral or subcutaneous administration of a calcium solution helps to prevent relapse [58]. Other treatment of Calcium-containing products that also contain phosphorus and magnesium, as well as dextrose, will have an additional therapeutic effect. Prevention is by supplementing adequate dietary requirement for calcium throughout gestation.

8.2 Pregnancy toxemia/ketosis

Is a metabolic often fatal disease that occurs in all parts of the world. It is most prevalent in very fat does or does carrying multiple fetuses. This is a condition of late pregnancy and early lactation most commonly occurring in the last month of gestation.

Causes: is caused by in adequate nutrition or disturbance in carbohydrate or sugar metabolism especially during last trimester of pregnancy in does. As the pregnancy progresses, the need for energy in the body increases, at the same time, the rumen capacity decreases as a result of fetal growth.

Clinical signs: Does with ketosis have poor appetite, lethargy and stress. They also tend to separate from the herd, lag behind and become depressed. There is abnormal gait and posture, apparent blindness with severe depression and frequent urination. A classic symptom is sweet-smelling (ketotic) breath. Goats may also grind their teeth and grunt, muscle tremors, opisthotonos, followed by recumbency (**Figure 24**, **Table 1**), coma and death usually follows within a few days.

Figure 24.
Goat with ketosis showing sternal recumbency. By author.

Diagnosis: To determine pregnancy toxemia in a flock. Blood glucose monitor should be used with a BHBA (beta-hydroxybutyrate) blood strip to test the glucose level. Does with a reading of 0.8 mmol/L or higher can be classified positive for pregnancy toxemia and should be treated accordingly.

Treatment and prevention: Administer a readily usable form of energy (especially glucose) and get the doe eating on her own usually with the help of anabolic steroids. Treatment is often ineffective if pregnancy toxemia is in advanced stages [59]. Oral administration of propylene glycol 1o0ml/day for three consecutive days may be helpful. Supplementation with calcium lactate may also be suggested. Subcutaneous administration of protamine zinc insulin at 0.4 U/kg daily may increase survival rate especially during the first half of pregnancy. Excessive fat should be reduced and weight gains should be allowed only during the 6 weeks before kidding will reduce the incidence of ketosis. Give high-quality forages in addition to supplements that are very palatable during the last 2 months of pregnancy. This allows does to receive adequate energy even though rumen volume is decreased.

8.3 Lactic acidosis (grain overload)

Is a carbohydrate fermentation disorder of the rumen that usually affect goats of all breeds and ages, as a result of feeding with large amount of highly fermentable concentrates, underfeeding of effective fiber and poor management practices.

Causes: occurs in goats that have been fed predominantly forage but abruptly introduced to a large of amount of readily digestible carbohydrates especially grain. It can be caused by abnormal feeding of an effective fiber and poor management practices.

Clinical signs: In acute acidosis, there will be sudden death. Other signs include an increased pulse and respiratory rates, decreased rumen motility, mild bloat, staggering, abnormal posture (**Figure 25**, **Table 1**) and even coma [60]. Subacute acidosis is difficult to recognize but occurs more frequently. Loss of appetite, panting, diarrhea, dehydration, lack of rumination and signs of discomfort may be noticed.

Diagnosis: The diagnosis is obviously based on history and clinical findings. It can also be confirmed by, a low rumen fluid pH (less than 5.5), and the absence of live protozoa when rumen fluid is examined under the microscope.

Treatment and prevention: Treatment usually includes drenching with a solution of sodium bicarbonate, Magnessium sulphate, administration of an antibiotic to suppress the lactic acid-producing bacteria and a change in feeding practices. Prevention

Figure 25.
Goat with grain overload.

involves slowly introducing concentrate feeds to allow the adaptation of rumen microflora. Provision of a properly balanced diet and proper feed management practices.

9. Conclusion

Animal diseases are global challenges that are considered as a major impediment to livestock especially goat production. To establish an early warning and proper implementation of strategic preventive measures in a country prone to disease affliction, focus should be made on identifying principal epizootic diseases that have a strong impact on the public health, social and economic significance. This work clearly identified the commonest diseases ravaging goats from infectious: bacteria, fungal, parasitic, protozoa, rickettsia and viral, to non-infectious: metabolic disturbance/ nutritional disorders and spells out the treatment regimen and the preventive measures that will remedy the predicament in goat production. It behooves on government, veterinarian, para-veterinarians and practioners to co-opt this idea and move forward to design a novel innovative policies and ideas that will help in the prevention, control and eradication of the diseases.

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Conflict of interest

The authors declare no conflict of interest.

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Chapter 7

Goat Parasitism, Diagnosis, and Control

Hafiz Muhammad Rizwan, Muhammad Sohail Sajid, Faiza Bano, Urfa Bin Tahir, Aayesha Riaz, Muhammad Younus, Mahvish Maqbool, Ali Butt and Hafiz Muhammad Zohaib

Abstract

Small ruminants, especially goats, play an important role in the livestock economy of the world. Parasitism is one of the major problems facing goat populations around the world and is responsible for production losses. To control these kinds of losses and improve production, a timely diagnosis of parasitic infection is crucial. The improvement and development of conventional and molecular diagnostic tests help a lot with the early detection of parasitic infections. Strategies to use different control measures like chemotherapy, phytotherapy, pasture management, the use of bioactive crops, biological control measures, and the development of vaccines also help to improve the health and production of goats.

Keywords: goat, parasites, diagnosis, control, prevention of parasitic infections

1. Introduction

Goats are said to be the earliest tamed animals on human-made farms. Several ancient pieces of evidence show that they have been supporting people and their fields for around 10,000 years [1]. There are around 861.9 million goats in the world; among these, 59.7% of the goats are present in Asia, as compared to the worldwide ratio. China maintained its lead in terms of goat availability, followed by India, Pakistan, and Bangladesh, which account for about half of the world's goat production load. Goats are commonly kept because they are less expensive to keep due to their small size, low food requirements, and lower care costs than cows [2]. Around 15.2 million metric tons of milk are produced by goats worldwide. In terms of goat milk output, India leads the way, with Sudan and Bangladesh trailing behind. Spain and France are the two largest producers of goat milk in Europe [3].

External and internal parasites significantly cause diseases in animals. These parasites cause permanent damage or death to animals, which can lead to economic losses and affect the performance of animals [4]. Overburdened parasites can impair reproductive capacity, limit growth rates, and make animals less productive for meat, fiber, or milk. Endo- and ectoparasites can infect goats and have been reported all over the world. Many nematodes and cestode species infect sheep and goats, causing parasitic

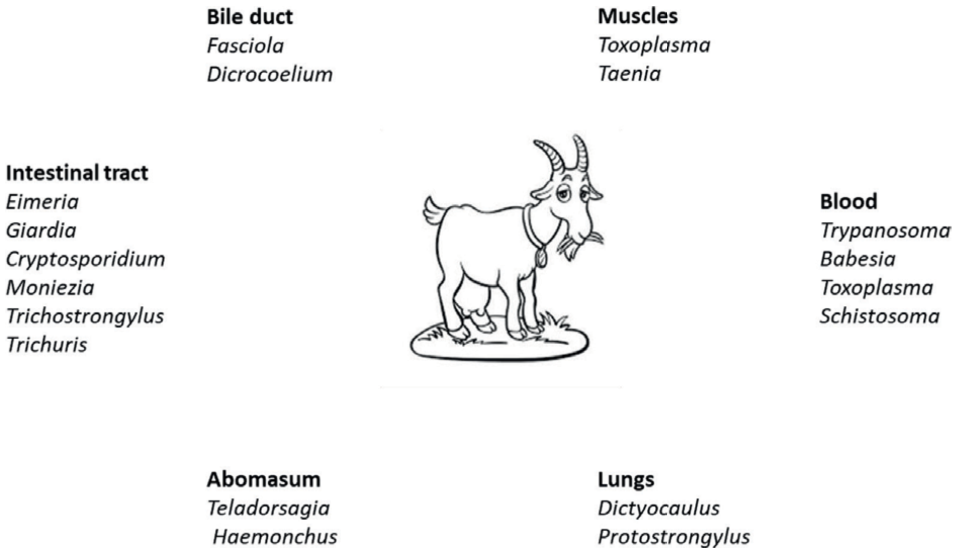

Figure 1.
Parasitic species affecting the different organs of goats (made by the author).

gastritis and enteritis. *Ostertagia circumcincta*, *Haemonchus contortus*, *Bunostomum trigonocephalum*, *Trichostrongylus axei*, *Oesophagostomum columbianum,* and *Nematodirus* spp. are the most significant and prevalent around the world [5]. Parasitic species affecting the different organs of goats are given in **Figure 1**. Arthropod pests reduce goat production while also causing damage to body tissue, skin, hair, and blood loss. These parasites produce sores, cause skin irritation, and make the animal feel uneasy. Arthropods act as vectors and transmit diseases from a sick animal to a healthy animal. To get rid of these arthropods, animals move unintentionally and damage themselves and other animals, which can reduce production and cause weight loss [4].

Fecal examination is one of the best techniques for detecting parasites in parasitic infections, particularly endoparasites. Fecal examination can help identify parasite species and the severity of infection. However, the fecal examination methods failed to detect infection in its early stages. Some alternative methods are currently exploited for the parasitological examination of infections [6]. Antiparasitic drugs can be used to control parasitic infections. But due to the irrational use of existing drugs, parasites are becoming increasingly resistant to standard antiparasitic agents [7].

2. Methodology

Goat raring and farming are the only sources of income for most farmers in the world, especially in developing countries like Pakistan, India, Bangladesh, etc. Most parasitic infections (especially chronic infections) are hidden killers for the economies of these farmers. Mostly, farmers are unaware of parasites, their diagnosis, their control, and their effect on the growth and production of goats. To obtain the related published research and data, we searched different databases (ScienceDirect, PubMed, ResearchGate, and available research papers with DOI). To search the data, the following keywords and subject terms were used: goat parasitism, protozoan infection, helminth infection, ectoparasitic infections, *Eimeria, Trypanosoma, Giardia,* *Cryptosporidium, Toxoplasma, Babesia, Fasciloa, Paramphistomum, Schistosoma, Dicrocoelium, Taenia, Moniezia, Trichostrongylus*. This chapter aims to compile all information on goat parasites, including pathogenesis, diagnosis, prevention, and control. Other than therapeutic control measures, alternative strategies (phytotherapy, biological control, grazing management, genetic management, and nutrition management) to control resistant parasites in goats are also discussed. Proper diagnosis of parasitic infections and strategic use of drugs can help reduce parasitic infections. The use of alternative parasite control strategies (pasture management, biological control, and phytotherapy) is crucial to reducing the production of resistant parasites.

3. Results and discussion

3.1 Protozoa

Protozoans are single-celled parasites that mostly infect the gastrointestinal (GI) tract and circulatory system. Protozoans may reproduce sexually as well as asexually. In amoebas and flagellates, reproduction usually occurs through asexual multiplication in the form of binary fission. In Apicomplexa, the division occurs both sexually and asexually. Some protozoan species only need one host to complete their lifespans, and some of them have complex lifecycles that require two separate host species.

The trophozoite stage is linked to the pathogenesis of parasitic protozoans. In hemoflagellates, different terms such as epimastigote, amastigote, promastigote, and trypomastigote are designated as trophozoite stages based on the presence or absence of flagella. Trophozoite stages of *Toxoplasma gondii* are known by various names in Apicomplexa, including tachyzoite and bradyzoite. Some additional sexual and asexual stages that are included in the lifecycle of the species of these phyla include gametes, gametocytes, and merozoites, that is, the ones arising from a multinucleate schizont's fission. Some protozoans also form cysts that have one or more contagious species. Upon multiplication in the cysts of some species, excystation occurs that releases more than one organism [8].

Protozoal parasites that cause coccidiosis to grow in the gut wall and can seriously harm the gut. *Eimeria (E.)* is a protozoon that causes coccidiosis. Only two (*E. caprina* and *E. ninakohlyakimovae*) of the nine different species of *Eimeria* found in numerous nations are capable of causing serious illness in goats. Other species do not infect goats or just show moderate symptoms [9]. Goat kids are most commonly infected, and this parasite has enormous potential for reproduction. Clinical symptoms may include a sudden onset of pasty diarrhea, abdominal pain, straining to pass feces and mucous, and blood-stained diarrhea [10].

Cryptosporidium is another protozoan parasite that can affect very young kids. This parasite causes diarrhea, which, if severe, can be fatal. Kids with compromised immune systems and insufficient colostrum intake are more likely to experience it. Moving young kids to the infected area, the use of artificial milk, and contaminated feed and water can also cause infection. The species of protozoa present in goat populations and their pathogenesis are given in **Table 1**.

3.2 Helminths

Helminths are also referred to as parasitic worms and are primarily classified based on their external and internal morphology. Trematodes (flukes), cestodes

Species	Predilection Site	Pathogenesis	Drug of Choice / Preventive Measure	References
Eimeria (E.) airlongi, E. caprina, E. ninakohlyakimvae, E. christenseni	Intestinal tract	Mild diarrhea to severe bloody diarrhea	Decoquinate, Monensin	[11]
Trypanosoma vivax	Blood	Pale mucous membranes, enlarged lymph nodes, weakness, weight loss, opacity of the cornea, blindness, and abortion	Diminazene aceturate	[12]
Giardia	Gastrointestinal tract	Chronic diarrhea	Fenbendazole, Albendazole	[13]
Cryptosporidium parvum	Gastrointestinal tract	Diarrhea	Nitazoxanide	[14]
Toxoplasma gondii	Muscles	Fever, diarrhea, cough, dyspnea, icterus, seizures, and death	Goats vaccinated with the commercial Toxovac S48 live vaccine	[8]
Babesia (B.) ovis, B. motasi	Blood	Fever, anemia, icterus, and hemoglobinuria	Imidocarb, Dipropionate, Diminazene aceturate	[15]

Table 1.
Species of protozoa present in goat populations and their pathogenesis.

(tapeworms), and nematodes (roundworms) are the three primary types of helminths. Except for blood flukes, helminths (tapeworms and flukes) have hermaphroditic species. Nematodes are the most prevalent class of helminths all around the world; they are bisexual and commonly called roundworms [16]. Nematodes are an important goat endoparasite and live in the gut and stomach.

Goats infected with nematodes shed parasitic eggs in their feces, which remain viable for a period of time, depending on temperature and humidity. During grazing, the infective stage (L3 on the grasses or L1 within the egg) is ingested by the goat and reaches its predilection side, where it causes damage. Nematodes, which belong to the genera *Haemonchus, Ostertagia, Nematodirus, Cooperia, Oesophagostomum*, and *Trichostrongylus,* are prevalent in goat populations. Diarrhea and weight loss are common signs in goats due to the presence of worms in the gut. *Haemonchus (H.) contortus* (Barber's Pole Worm) is present in the abomasum (the fourth stomach) and causes anemia because they suck blood. Nematodes are important in goats as compared to sheep and cattle because they have low immunity and are susceptible to re-infection [17].

Cestodes are segmented, flat, and quite long worms present in the gut of the goat. One of the main species is *Moniezia*. The eggs or gravid segments are passed in the feces and ingested by oribatid mites (intermediate hosts). During grazing, goats ingest this mite along with grasses and get the infection. Most tapeworm infections are nonpathogenic, but heavy infections can lead to blockage of the

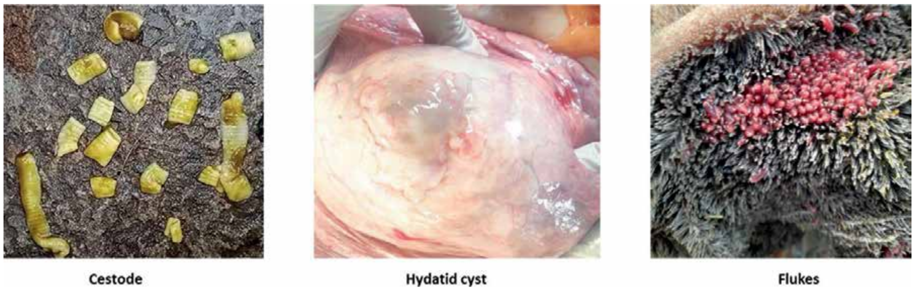

Figure 2.
Helminths collected from slaughtered goats (made by the author).

intestine, GI disturbances, and thriftiness [18]. Flukes like *Dicrocoelium dendriticum, Paramphistomum* spp., *Cotylophoron* spp., and *Fasciola* spp. are commonly found in the goat population. Some of the helminths collected from slaughtered goats are given in **Figure 2**. All trematodes have an indirect life cycle, and the snail is one of the compulsory intermediate hosts. Some trematodes need another intermediate host other than a snail to complete their life cycle [19]. The species of helminths present in goat populations and their pathogenesis are given in **Table 2**.

Specie	Predilection site	Pathogenesis	Drug of Choice / Preventive Measure	References
Fasciloa (F.) hepatica, F. Magna	Bile duct	Progressive weight loss, anemia, edema (build of fluid, typically under the jaw), and sudden death	Triclabendazole, Albendazole	[20]
Paramphistomum cervi	Rumen	Diarrhea, anemia, lethargy, and often result in death if untreated	Hexachlorophene, Oxyclozanide	[21]
Schistosoma (S.) japonicum, S. indicum	Blood	Fever, chills, cough, and muscle aches	Praziquantel	[22]
Dicrocoelium dendriticum	Bile duct	Eosinophilia, abdominal distention, painful liver, right upper abdominal pain, diarrhea, constipation, and anemia	Albendazole, Netobimin	[23]
Taenia ovis	Cranial cavity, heart, and other muscles	Chewing abnormalities, or ill-thrift, depending on which muscles are affected. Sudden death	Cook meat to safe temperatures	[24]
Moniezia caprae	Small intestine	Obstruct the lumen of the intestines	Niclosamide, Albendazole, Pasture renovation	[25]
Teladorsagia circumcincta	Abomasum	Diarrhea, anemia, and hypoproteinemia	Albendazole	[26]
Trichostrongylus	Small intestine	Watery diarrhea	Albendazole	[27]

Specie	Predilection site	Pathogenesis	Drug of Choice / Preventive Measure	References
Trichuris ovis	Cecum and colon	Feces, anorexia, and anemia	Albendazole, Mebendazole	[28]
Dictyocaulus (D.) viviparus, D. filaria	Bronchi	Coughing	Ivermectins, Milbemycins, or Levamisole	[29]
Protostrongylus	Bronchioles	Coughing	Milbemycin, Oxime+praziquantel	[29]
Haemonchus contortus	Abomasum	Failure to thrive and weight loss, severe anemia, lethargy, weakness, increased respiratory and heart rate, dark mushy feces	Levamisole	[30]

Table 2.
Species of helminths present in goat populations and their pathogenesis.

Worldwide, helminth infections in animals are the cause of many common and economically significant diseases. In essence, these parasites represent a risk to any livestock with outside access. Even though helminth infections can sometimes result in significant mortality rates, they typically influence overall health and welfare and lead to hidden productivity losses like lowered weight gain, milk supply, and wool and hair growth [22, 26, 30].

3.3 Arthropods

Arthropods are classified into insects and arachnids. Insects include lice, fleas, bugs, and flies, while arachnids include ticks and mites.

3.3.1 Insects

Goat lice are host-specific and only present on goats, or sometimes on sheep. Three biting species of lice, *Bovicola (B.) caprae*, *B. limbata,* and *B. crassipes,* are the main species of goat lice. These species feed on hair and skin and cause dermatitis. Three blood-sucking lice species of goats are *Linognathus (L.) stenopsis*, *L. africanus*, and *L. pedalis*. The *L. stenopsis* can be present all around the body, the *L. africanus* is usually found around the neck and head regions, and the *L. africanus* is found on the legs and feet of goats [31].

Itching, irritability, and scratching are all symptoms of pediculosis brought on by lice infestation. The lice infestation can be identified by the matted and dull coat of the animal, grooming behavior, and excessive scratching. Due to irritation caused by louse bites, animals scratch and rub with different objects, which can lead to skin damage and hair loss. Production losses and weight loss were reported due to improper nutrition, restlessness, and nervousness, while heavy infestation may lead to anemia. Within a herd, lice infestation can be transmitted through direct contact, while herd-to-herd infestation can be accomplished by introducing the infected animals. Lice can also move from one farm to another by clinging to flies [32].

Small (1 mm to 8 mm), wingless fleas with flattened sides and spines (combs) facing backward are known to infect goats. The majority of species move around a lot and only stay on the host for a portion of the time in order to feed on blood. The legs are strong and can be used to jump large distances. The *Ctenocephalides felis* (cat flea) and the *Echidnophaga gallinacea* (sticktight flea) are two species that frequently infest goats. Domestic goats have reported cases of severe anemia linked to a lot of cat flea bites. *E. gallinacea* tightly adheres to its host, typically near the ears and face. This species can stay attached to its host for 2–3 weeks and may spread in large populations, leading to ear and head ulcers. If fleas become an issue in a goat herd, extra precautions for monitoring herd dogs should be put in place because both of these flea types are quickly transferred to other animals [33].

Flies undergo a complete metamorphosis (eggs, larvae, pupae, and adult stage), and each stage inhabits a different habitat. Goats are particularly sensitive to species of flies like horn flies, stable flies, black flies, house flies, blow flies, mosquitoes, and horse flies. Flies can be extremely annoying and may have an impact on the goats' performance. They prevent grazing and make goats group together or flee in order to escape their annoyance. Flies can bite (which is very painful) or suck blood, which can cause significant irritation to goats and transmit several diseases [34].

Horn flies are a common problem for cattle, but they can also occasionally be seen on goats, especially when goats and cattle use the same pasture. Both female and male horn flies feed on the blood of the host between 20 and 30 times a day. Horn flies remain on the animal constantly, only leaving to lay their eggs [35]. Stable flies (medium-sized flies) are similar to house flies and prefer to remain on goats' feet and legs. Stable flies bite their hosts in a highly painful way and cause damage. On the biting side, blood may ooze out, which may be fatal in cases of heavy infestation. Goats on pasture frequently gather and mill around in large numbers due to stable fly infestations. Stable fly larvae grow on filthy hay, spilled feed, and straw bedding that is damp and decomposing organically [36]. Although some types of black flies and mosquitoes can feed on goats, they are typically not present in large enough numbers to cause huge damage. During the late spring season, the population of black flies and mosquitoes increases. Both of these flies require bodies of water to develop their larvae. Mosquito larvae grow in stagnant water, while black fly larvae develop in moving water. The greatest danger posed by mosquitoes is that they can spread disease [37].

House flies have a simple sponging mouthpart and do not bite goats. House flies do not directly harm animals but can irritate them and act as mechanical vectors for different pathogens. House flies can be a serious nuisance to confined animals, especially young goats. The attack of house flies increases when animals and sheds are not cleaned properly. Lacrimal, nasal, oral, and other goat secretions attract house flies. House flies rarely bother pastured goats unless they frequently visit loafing shelters. Although blowflies do not bite goats, they may be very annoying to both animals and livestock handlers, like house flies. The larvae of blowflies and houseflies grow in rotting organic waste, and decomposing animal remains. The best way to prevent these flies around barns is to practice good cleanliness. Premise sprays can be used inside buildings to suffocate adult flies. To expose flies to insecticide residue, surface areas in barns can be sprayed with premises sprays [38].

The adult nose-bot fly does not cause any harm to animals, but larvae live in goats' nostrils. Larvae mature in the head sinuses before moving back down the nasal passages and finishing their development on the ground. Nasal membranes become inflamed as a result of migrating larvae (migrating to and from the head sinuses). Secondary infections can develop at the sites of migration. Animals that are infected show symptoms that include grinding of teeth, loss of appetite, excessive head shaking, and nasal discharge. A nose-bot infestation can also be identified by the presence of blood specks in the nasal discharge. When mature bot flies are present, goats exhibit unusually excitable behavior [39]. Ivermectin is very effective against larvae in all stages. Eprinomectin and doramectin are some other medications that have been said to be effective [40]. Keds are wingless flies that live their whole lives on goats or sheep. The transmission of keds from one to the other occurs through direct contact. *Melophagus ovinus* (sheep keds) is a problem in sheep but can also occur in goats. During her six-month life span, a female sheep kid gives birth to 10–15 young (one every eight days). The mouthparts of adult kids, which are sharp and resemble mosquito stingers, are used to feed. The feeding behavior of sheep kids causes severe irritation, and the animal rubs, bites, and scratches the body with other objects [41]. This condition is known as "cockle," which decreases the market value of hide because it weakens and discolors it [42].

3.3.2 Arachnids

Several species of mites can infest the goat. The most common species of mites that infest goats are *Demodex caprae* (goat follicle mites), *Psoroptes cuniculi* (ear mites), *Sarcoptes scabiei* (scabies mites), and *Chorioptes bovis (*chorioptic scab mite*)*. Demodectic mange is caused by *Demodex caprae*, which can produce cutaneous papules and nodules. These nodules or papules are caused by gland ducts or hair follicles becoming clogged and forming swellings. Demodectic mange mostly affects pregnant, dairy, and young goats. Nodules may burst and release mites, which could spread the mite to other animals. Close contact with infected animals, especially during mating or mingling, and the licking of infested animals are other means of mites' transmission. Sarcoptic mange is caused by the scabies mite, which can burrow into the skin and cause varying degrees of dermatitis. In goats, a mild infestation of sarcoptic mange can be resolved without any severe clinical signs. However, in heavily infected goats, extensive hair loss (around the eyes, ears, and muzzle) and crusty lesions can be observed. *Psoroptes cuniculi* (ear mites) infestation causes lesions in or on the ear. These lesions result in the development of a crust and the discharge of an unpleasant odor into the external ear canal. The behavioral reactions due to ear mange include ear scratching, spasmodic contractions of neck muscles, loss of balance, and head shaking. Goats that are typically younger than a year typically have greater rates of infection than older animals. Weight loss and anemia are commonly seen in goats with chronic infestations of these mites [43]. In goats and domestic animals, chorioptic mange is caused by *Chorioptes bovis*. Common sites of infestation of this mite are the legs and feet of goats, especially the forefeet. These mites can also be found higher on the foot. Most lesions are small and barely noticeable. To get rid of mites' infestation, treatment and control efforts should concentrate on all the animals in a herd. Retreatment of animals is necessary between 10 and 12 days to kill the newly hatching eggs. Isolating new animals should be performed to reduce the chances of mite introduction into herds [44].

Tick infestations not only damage the hide of animals but are also responsible for blood loss and the transmission of several pathogens. Ticks are divided into three groups (one-host, two-host, and three-host ticks) on the basis of the number of animals required to complete their life cycle. Ticks that parasitize goats are primarily members of the three-host tick family. Three-host ticks require three different animals to complete their whole life cycle, which can make their control challenging.

There are three types of ticks known to parasitize goats, despite the fact that they are not frequently observed on goats. *Dermacentor variabilis* (American Dog Tick), *Amblyomma maculatum* (Gulf Coast Tick), and *Amblyomma americanum* (Lone Star Tick) are commonly found on goats [45].

Arthropod	Specie	Predilection site	Pathogenesis	Drug of Choice / Preventive Measure	References
Lice	*Bovicola (B.) caprae, B. crassipes, B. Limbata, Linognathus (L.) stenopsis, L. africanus, Linognathus pedalis*	skin	Loss of hair, weight loss, anemia	Insecticide application	[31]
Mite	*Demodex caprae, Sarcoptes scabiei*	skin	Dermal papules and nodules, hair loss around the muzzle, eyes, and ears; lesions on the inner thighs	Delayed egg hatch requires retreatment at 10 days to 12 days	[43]
Flea	*Ctenocephalides felis, Echidnophaga gallinacea*	Head and ears	Extreme annoyance, irritation, loss of hair, anemia and loss of body weight	Applying Frontline	[33]
Ticks	*Dermacentor variabilis*, *Amblyomma maculatum*, *Amblyomma americanum*	Horns, neck areas, head and arm-pit regions	Damage to the skin and hide, limping	Applying Frontline	[45]
Flies	*Oestrus ovis*	Dorsal turbinate bones, frontal sinuses	Violent sneezing	Fly predators, ClariFly® Larvicide, proper manure management	[40]
	Gasterophilus haemorrhoidalis	Larvae migrate to the head sinuses	Discharge from nostrils, extensive shaking of the head, loss of appetite, and grating of teeth	Ivermectin	[33]

Table 3.
Species of arthropods infesting the goat population and their pathogenesis.

The neck and withers are common *A. americanum* infestation sites on goats. Ticks can sometimes be found in the armpits and on the head. The lone mark on the back of adult females makes them easy to identify. The rear edge of adult males has non-connecting white marks. As compared to other ticks, the mouthparts of this tick are substantially longer. According to studies, goats can act as reservoirs for the bacteria *Ehrlichia chaffeensis*, which is transmitted by Lone Star ticks and causes the disease known as monocytic ehrlichiosis in humans. Due to this kind of zoonotic importance, care should be taken to handle goats infested with *A. americanum* [46]. According to a seasonal cycle, the infestation of goats by Gulf Coast ticks starts in the early spring and lasts until mid-summer. Throughout the summer, goats are infested with Lone Star ticks and American Dog ticks. All of these tick species should be controlled by targeted acaricidal applications; however, repetition may be necessary after three weeks. Extreme caution should be exercised when choosing an acaricide to treat the goats because there are very few approved acaricides for use in goats [47]. Species of arthropods infest the goat population, and their pathogenesis is given in **Table 3**.

3.4 Trends to diagnose goat parasitism

Infected animals' clinical signs and symptoms vary depending on parasite predilection sites and feed requirements. For example, if the parasite is disrupting the digestive tract, the most common signs associated with this infection are diarrhea, weight loss, a rough coat, depression, and anorexia. If a parasite is infecting the stomach or liver and consuming blood, then the common signs are anemia, pale mucous membrane of the inner eyelid, and weight loss. Laboratory findings in such cases include plasma protein loss, decreased packed cell volume, and an increase in fecal egg count.

3.4.1 Conventional methods

The fecal egg count (FEC) is a technique used to assess how many parasite eggs are expelled per gram of feces (EPG). Although this is the best technique for use with live animals, there are some measuring challenges, such as the fact that the EPG does not indicate the number of worms because adult worms of each parasite species lay a different number of eggs. Identification of eggs does not mean the exact identification of parasitic species, and some EPG determination procedures could be less accurate than others.

It has been demonstrated that the FEC, in particular for *H. contortus* (the barber pole worm), primarily reflects the animal's worm burden and acts as a seasonal signal of variations in the degree of infection. The relative direction of infection can be seen by looking at trends in FEC over time. When worms other than *H. contortus* are prevalent, FEC is a less reliable indicator of adult worm loads [48]. Some diagnostic laboratories may also offer services for the culture of feces in order to hatch worm eggs and collect larvae. This makes it possible to recognize the specific species of intestinal or abdominal parasites present in the herd. To determine the degree of resistance against anthelmintics, "drench-rite tests" can be performed to choose the best effective drug [49].

The maintenance of an animal's "erythropoiesis," or capacity to produce red blood cells, can be impacted by nematode parasites. The percentage of red blood cells in the blood is known as the packed cell volume (PCV). The normal value of PCV typically exceeds 30%. Anemia usually manifests itself when PCV falls below 20%. Nematode infection may lead to chronic anemia, which means red blood cell production is not as fast as needed to meet demand. Notably, *H. contortus* can cause severe acute blood loss and mortality. The PCV readings are not always used as a "stand-alone" diagnostic tool; they have been used to complement other response criteria [50].

To determine the level of anemia, the color of the mucous membrane (where several capillaries are close to the surface) of animals like the gums, the vulva, and the eyelid can be observed. If these membranes are extremely pale, deworming is necessary right away since death is imminent. In South Africa, the FAMACHA eye color chart method was created to assist farmers in monitoring and assessing the degree of anemia without the need for laboratory testing. This method involves looking at the lower eyelid mucous membranes and comparing them to a laminated color chart with sheep eyes at five various levels: 1) Red means non-anemic, 2) red-pink means non-anemic, 3) pink means mildly anemic, 4) pink-white means anemic, and 5) white means severely anemic.

This approach can be useful for identifying animals that need therapy. But this technique is only valid for blood-sucking nematodes like *H. contortus*, as anemia is the main pathologic consequence of infection. The comprehensive testing of FAMACHA in South Africa and the US produced remarkable results. It has been shown that if animals were checked weekly and only salvage treatments were given, up to 70% of adult animals would not require deworming, and only a small number would require more than one treatment. The overall number of treatments may be reduced by up to 90% as compared to earlier treatment plans. This prevents the development of dewormer resistance because the majority of the worms would not be exposed to anthelmintics [51, 52].

The direct and absolute method for identifying and determining the exact number of parasites is to examine the animals immediately after slaughter or death to collect, count, and identify the parasites present. Only a veterinarian or other qualified specialist can perform this with high precision. *Haemonchus contortus,* which is present in the lining of the abomasum, can help determine the severity of the infection. It should be noted that the animal must not have been dead for very long. The likelihood of discovering worms increases with how recently the animal died. This is due to the fact that the worms will eventually travel as deep down the intestine as they can after dying. *Telodorsagia* and *Trichostrongylus* must be noted as being too small to be seen without a microscope. Even if thousands of these worms are present, they are hidden by the contents of the stomach and are invisible to the naked eye [49].

3.4.2 Serology-based assays

In live animals, where tissue or biologic samples are inaccessible, the identification of parasitic infection through a serology-based assay is the gold standard. Antibody and antigen detection are the two categories of serology-based diagnostic assays. Enzyme-linked immunosorbent assay (ELISA) is an important serology-based assay with different types like the Falcon assay screening test, ELISA, and dot-ELISA. Other serology-based tests used for identification of parasites include the hemagglutination (HA) test, the complement fixation (CF) test, the indirect immunofluorescent antibody (IFA) test, the direct immunofluorescent antibody (DFA) test, the immunoblotting test, and quick diagnostic procedures [53].

Serology-based tests are more specific and sensitive, even though they are easier to use and take less time to complete. It is crucial for differential diagnosis in animals where blood smears fail to identify the parasite, for example, *Babesia* and *Plasmodium* infections, or in animals with low parasitemia or asymptomatic infections [54]. It is possible for the parasite to spread after organ or blood transplants if an infected patient is asymptomatic and declared negative. When egg production is low or irregular, serology testing for the parasitic infection has been demonstrated to be helpful in confirming the chronic infection [55]. Due to antigenic variation, the sensitivity and specificity of a serology assay can vary in different regions. A serology assay of one parasitic infection can also show cross-reactivity with other related parasites due to the presence of the same antigens.

3.4.3 Nucleic acid-based approaches

Due to the limitations of the above-mentioned assays (microscopy and serology assays), scientists developed the polymerase chain reaction (PCR), which amplifies the specific genes of a specific parasite. With the advancement in diagnosis, traditional PCR is updated to nested PCR (improving sensitivity and specificity), multiplexed PCR (amplification of several different DNA sequences at the same time), and real-time PCR (quantification of the product after each cycle). Luminex-based assays and loop-mediated isothermal amplification are new emerging techniques for the identification of parasitic infections [53, 56]. The sensitivity and specificity of nucleic acid-based techniques are much higher than those of existing diagnostic assays. In addition, nucleic acid-based techniques can detect infection in animals with low parasitemia or even asymptomatic infection [57].

3.5 Prevention and control of parasitic infections

Parasitic protozoan infections have long been regarded as one of the world's most serious unresolved livestock and public health issues, particularly in most tropical regions. Leishmaniasis, coccidiosis, and American and African trypanosomiasis account for the highest mortality rates in developing countries because of a lack of hygienic practices and inefficient prophylactic measures [58]. Most of these diseases were thought to be extinct in developed countries, but they are now resurfacing as opportunistic infections, typically in immunocompromised people. The emerging of these diseases may be a result of tourism, immigration flows (particularly from endemic areas), and global warming brought on by dramatic climatic changes [59].

The development of protective vaccinations has been the subject of parasitology, but their effectiveness is still not progressive. Chemotherapy is still the mainstay of care for the majority of parasite infections. The drugs that are currently being used were first launched decades ago, and some of them even have significant effects. But due to the irrational use of most of the anti-protozoal drugs, their efficacy has decreased. In the past few years, there has been little success reported in the development of new anti-protozoal drugs. However, due to recent technological advancements, research has been done to develop new antiparasitic drugs. The establishment of public-private partnerships that concentrate on tropical parasitic diseases and the sequencing of parasitic genomes are the two most significant developments [60]. The control of parasites, especially helminths, relies on pasture management practices, routine checkups of animals, efficient use of chemotherapeutics, and strict adoption of hygienic measures.

Arthropods may be a problem for man because they contaminate his food and other resources. Arthropods spread several infectious diseases to animals and irritate or harm them directly. For these reasons, man may need to control, eliminate, or repel them. When arthropods are present around goats, they can cause a significant problem. Insecticide-based control should be required to reduce damage and production losses. Permethrin- or pyrethroid-based products are the only ones that have been allowed to treat goats. Those that contain piperonyl butoxide deliver the best results when combined with pyrethroid products. When only treating the barns, goat farmers have more alternatives, which are frequently referred to as "premise sprays." As opposed to a non-residual substance like pyrethrum, a residual spray that lasts for a while is the best choice for a premises spray. Make sure to treat vertical arthropod-resting places, such as barn walls, while using residual sprays. When applying the product, make sure the surface is neither greasy nor moist. Automated misting systems are now being used by more livestock owners who keep their animals mostly in barns. These can be useful, but caution should be exercised when using them, especially if there is hay or animal feed nearby. Insecticide resistance might also develop as a result of excessive use of these systems [38]. Other means to control arthropods are physical measures (such as heat or cold), biological interference, the use of chemical repellents, trapping of arthropods, and destruction of their habitat.

3.6 Alternatives to antiparasitic drug treatment

3.6.1 Use of herbal anthelmintics

In animals, parasites can cause acute and chronic infections, which ultimately reduce production (growth rate, milk production, and meat production). Along with the systematic use of antiparasitic agents, research has shown the positive role of complementary and alternative medicine in treating parasitic infections. Various plants or plant products have been traditionally used in veterinary medicine for their antiparasitic activity. The need of the hour is to standardize the use of these phytogenic substances for parasite control at the farm level. Indigenous plants that can be used for their antiparasitic effects include *Heyysarvum coronarium, Heracleum* spp., *Allium sativum, Artemisia maritime, Melia azadarach, Artemisia vulgaris, Chrysanthemum* spp., *Areca catechu, Calotropis procera, Carica papaya,* and *Azadirachta indica* [61, 62].

The juice of crushed leaves of *Aloe ferox* can be applied to the skin to treat tick and mite infections, and if this juice is used with drinking water, it can control the helminth infection. *Elephantorrhiza elephantina* root boiling water can be used to treat arachnid (spray on skin) and helminth (drinking water) infections. Boiling the leaves of *Acokanthera oppositifolia* and *Bulbine latifolia* is very useful to control all kinds of parasitic infections. An extract of the bark of *Centella coriacea* and *Cussonia spicata* and an extract of the leaves of *Agapanthus praecox* and *Albuca setosa* have shown anthelmintic effects [63].

3.6.2 Biological control

Biological control of parasitic infections can be done either by using agents of plant origin, like grasses, or agents of zoological origin, such as bacteria, viruses, fungi, predators, and parasites. Fungi having antiparasitic activity have been known for a long time. Fungi are divided into three groups based on their morphology, spectrum, and efficacy. One is the predacious fungi, which have specialized structures to trap nematodes on their mycelium, such as adhesive knobs, rings, and networks. Important predatory fungi include *Monacrosporium* spp. and *Arthobotrys* spp. [64]. *The second* group consists of the endoparasitic fungi, which produce spores.

Examples include *Harposporium anguillulae* and *Drechmeria coniospora* [65]. The third group includes egg parasitic fungi that have ovicidal activity and can be pivotal in the control of those nematodes that are capable of surviving for longer durations in the environment in the egg stage. *Verticillium chlamydosporium* has been shown to be effective against *Ascaris lumbricoides* eggs from naturally infected pigs [66].

3.6.3 Grazing strategies

Stocking density is an important aspect of controlling parasitic infections, as it is directly linked to the exposure of animals to infective larvae as well as pasture contamination. A general guideline considers five sheep or five to seven goats equal to one cow, and it is suggested to graze five to seven goats per acre of pasture. Sheep and goats have different grazing habits. Sheep prefer grazing on the ground, while goats prefer to browse on trees and bushes. Pasture management also includes careful inspection of the grazing area to avoid overgrazing and sustain productive pastures. It includes the use of a grazing area that is not contaminated with parasitic larvae and has not been used for grazing sheep and goats over the last 6 to 12 months, but it could be used for grazing cattle or horses. It also includes the removal of silage crops or hay. The burning pasture will eliminate parasitic larvae [67].

3.6.4 Genetics management

It is the best and most long-term remedy to control parasitic infections, as some breeds of animals are more resistant to parasitic infections. Selecting animals for parasitic resistance can be an important tool in this regard, and it does not have any bad effects on the animal's growth. Nowadays, breeding policies are concentrating on the development of breeds that are resistant to parasitic infections. This trait has a heritability of 20–40%. Grazing resistant animals with susceptible animals on the same pasture can reduce the challenge to susceptible animals as resistant animals may act to sweep the pasture [68].

3.6.5 Nutritional management

Nutritional management plays a key role in controlling parasitic infections. The animals' protein intake is directly related to their ability to resist nematode infections. Protein-deficient animals have poor immunity due to lower levels of IgA and are thus less resistant to parasitic infections. Vitamins such as A, B_{12}, and E and minerals like Fe, Cu, Co, Zn, and P also provide a better immunity against parasitic infections. The addition of molybdenum at 6–10 mg/day has resulted in a decreased worm burden in lambs, which is not attributable to copper deficiency. A probable reason could be an increase in blood eosinophil levels and jejunal mast cells due to molybdenum administration [69].

3.7 Conclusions

The goat population contributes greatly to the world economy and plays a role in food security. Goat raring necessitates minimal infrastructure and investment. Like other animals, goats are also susceptible to both endo- and ectoparasites. Parasitic infection reduces the production (of milk, meat, and hair) and is responsible for economic losses. Internal parasites (protozoa and helminths) damage the organs, especially the gastrointestinal tract, and reduce the absorption of digested food. External parasites (lice, fleas, flies, ticks, and mites) damage the hide, are responsible for blood loss, and transmit several pathogens. The timely diagnosis of parasitic infections reduces the damage and production losses. With the advancement of diagnosis, parasitic infections can be detected easily and more accurately. Several antiparasitic drugs are available to treat parasitic infections, but irrational uses of these drugs can develop resistant parasites. Alternative techniques like phytotherapy, biological control, grazing management, bioactive crops, and nutrition are in practice to reduce the chances of parasitic resistance.

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Chapter 8

Survey of Endoparasite and Parasite Control Practices by Irish Goat Owners

Theo de Waal and Laura Rinaldi

Abstract

Goat farming is still in its infancy in Ireland. The purpose of this study was to survey goat farmers on their knowledge and current control practices of parasites as well as some information on the specific gastrointestinal parasite fauna of goats in Ireland. The main farming enterprise was cheese (46%) production and the majority of farms (55%) practising a pasture-based grazing system. Anthelmintics was regularly used on all farms with visual appraisal most commonly used (73%) to calculate animal weight. Anthelmintic dose given ranged from the recommended sheep dose (22%) to twice the recommended sheep dose (33%). A variety of different nematode, trematode, cestode and protozoa parasites were detected in the pooled samples. The prevalence of Eimeria spp. was the highest ranging from 79 and 100% in the adult goats and kids, respectively. Prevalence of trematodes ranges from 3 to 17% in adult goats, while none were detected in the kids. Of the gastrointestinal nematodes, strongyle eggs were most prevalent in adult (69%) and kids (42%). This first report on endoparasitic infections of goats in Ireland reveals a high prevalence of endoparasites and that farmers still uses inappropriate and unsustainable parasite control practices, highlighting the need for further education.

Keywords: goats, parasite control, endoparasites, survey, goat farming

1. Introduction

Goat farming in Ireland is still very much in its infancy, with only a small number of goat farms with the main emphasis on milk and cheese production. During the latter years of the last decade, there was a major influx of new entrants into the goat industry in Ireland, and data from the 2021 National Sheep and Goat Census (https://assets.gov.ie/226265/1598c686-c575-414d-9719-33ff1ff3c72d.pdf) recorded 735 registered herds representing a total number of 8077 goats. However, by far the majority (66.5%; n = 489) of the herds are very small, <5 goats/herd, and only 13 herds (1.8%) reported herd sizes of >100, representing 3051 (37.8%) goats.

Gastrointestinal helminths (GIH) affect the health and productivity of goats on pasture worldwide, and the frequent use of anthelmintic drugs is still the most common method used for controlling infection. This has led to the widespread development of anthelmintic resistance [1]. Resistance to two or more anthelmintic drug classes has been extensively documented in goat nematodes worldwide [1].

Although the GIH infecting sheep and goats are very similar the majority of studies on host–parasite interactions have been conducted in sheep and extrapolated to goats, but this may not reflect the true picture [2]. For example, the immune response in goats against GIH is less efficient in limiting helminth populations [2–5]. Studies have also shown that, in dairy goats in particular, there are similar GIH infection levels between adult and young animals, whereas in sheep adult ewes are usually much less heavily infected [5, 6]. Also, goats seem to be less able to control challenge infections compared to sheep, probably because the "immune memory" in goats does not last as long as in sheep [3, 7]. Therefore, an understanding of the GIH infecting goats is essential to improve the productivity and control of GIH in grazing goats. Furthermore, in many jurisdictions, the registration of anthelmintic drugs does not discriminate between sheep and goats, but several studies have shown that goats, due to their higher metabolic rate, require a higher drug dose to maintain the same plasma concentrations and half-life as other similar species [6–9]. The route by which anthelmintic may also be important in goats as one study have shown that macrocyclic lactone drugs are most effective in goats when administered orally [10].

Several surveys on helminths and anthelmintic resistance have been conducted in sheep flocks in Ireland [11–13]. However, very little is known about helminths and anthelmintic usage in Irish goat farms. This study aimed to survey goat farmers on their knowledge and current control practices of parasites as well as some information on the specific GI parasite fauna of goats in Ireland.

2. Materials and methods

2.1 Questionnaire

Goat owners that were members of Teagasc, the Agriculture and Food Development Authority of Ireland, were invited to participate in this study. Owners who confirmed their participation were sent a questionnaire and faecal collection kit with instructions on how to collect and send samples to the University College Dublin Parasitology laboratory (UCD PL). The questionnaire consisted of 27 questions and was divided into four parts, (i) basic farm information, (ii) goat herd demographics such as the main breeds, flock size, and kidding season, (iii) grazing management including pasture characteristics, grazing and housing periods, supplementary feeding and co-grazing species, and (iv) antiparasitic treatment and control practices, that included the frequency of treatments, dose determination, anthelmintic products used, perceived efficacy of the treatments and the source of information regarding worm control.

2.2 Sampling and laboratory procedure

Owners were instructed to collect faecal samples from 15 randomly selected adult (>18 months of age) and 5 kids (<12 months of age). Individual samples were placed in faecal pots (Sarsted, Germany), marked and placed into zip-seal bags before being posted to UCD PL.

When the samples were received at UCD PL, they were immediately vacuum packed [14] and couriered to CREMOPAR, Italy, where the parasitological analysis was performed [15]. Briefly, equal amounts (approx. 2 g) of faeces from each sample were pooled into four pools of five individuals (where possible). Faecal egg counts were performed on each pooled sample using the FLOTAC dual procedure [16, 17] with a detection limit of six eggs per gram of faeces (EPG). To detect and count gastrointestinal nematodes, cestodes and protozoa, a sodium chloride flotation solution (NaCl, specific gravity = 1.200) was used, while a zinc sulphate-based flotation solution ($ZnSO_4$ specific gravity = 1.350) was used to detect and count trematode eggs and lungworm larvae. All data were recorded in an Excel spreadsheet.

2.3 Data analysis

Data from the questionnaire and faecal analysis were entered on Microsoft Excel (Microsoft 365, Version 2301) and analysed using Epi Info™ (2021 Version 7.2.5.0). Descriptive statistics for each question were analysed. To determine the percentage responses to each question, missing data were excluded from the total number of responses. In the results, the total number of responses (n) are indicated for each percentage.

Parasitological data were summarised as proportion or averages, and 95% confidence intervals (CI) were calculated using Epi Info™ (2021 Version 7.2.5.0). The mean abundance of parasite infections was assessed from the pool faecal samples examined. In this survey, the nomenclature described by Bush et al. [18] was used.

3. Results

3.1 Questionnaire

A total of 64 goat owners were invited to participate in the survey and 11 (17%) agreed and returned questionnaires with accompanying samples. The flock size on the majority of farms was less than 100 (n = 5; 50%) with a mean of 23 (range 6–38) adult goats and 20 (range 3–39) kids (**Table 1**) and included a mixture of different breeds (**Table 2**, **Figures 1–3**).

Although the main kidding season was spring (n = 10; 91%), kidding also occurred during other seasons (**Figure 4**). The main farming enterprise was cheese (n = 5; 46%) or milk production (n = 4; 36%) (**Figure 5**). Five farms (45%) kept animals

Number of adult goats	Number of farms	Mean number of adult goats (min-max)	Mean number of kids (min-max)
<100	5	22.6 (6–38)	19.8 (3–39)
101–200	3	168.7 (150–200)	200.0 (40–360)
>201	2	245.0 (240–250)	80.0 (40–120)

Table 1.
The number of goats kept on the farms participating in the survey.

Breed	Number of farms
Saanen	5
Toggenburg	3
Old Irish Goat	1
British Alpine/Alpine cross	4
French Alpine cross	1
Anglo-Nubian/Nubian cross	2
Boer Goats Cross	1

Table 2.
Goat breeds kept by farms participating in the survey.

Figure 1.
Anglo-Nubian goats, which is a cross-bred between native British goats and a mixed population of large lop-eared goats imported from India, the Middle East and North Africa. Photo © Garry Dickinson (cc-by-sa/2.0).

indoors year-round, while three farms (27%) had year-round grazing, and the remaining farms (n = 3; 27%) turned goats out onto pasture in early spring (March or April) until late autumn (October to November).

Of the farms that turn out animals onto pasture, half (n = 3) also co-graze with other ruminants (**Figures 6** and 7). On all farms, goats were fed concentrates but also received several other feedstuffs and on four farms (37%) goats did not graze any grass (**Figure 6**).

The main parasite control practices and anthelmintic use are summarised in **Table 3** and **Figure 5**. In general, the majority of respondents (n = 9) indicated that they treat all the animals, but only a few (n = 3) treat animals following a set programme

Figure 2.
The South African Boer goat – One of the largest goat breeds. Photo by Die_Berlinerin from Pixabay.

Figure 3.
The critically endangered Old Irish goat. Photo by Angela from Pixabay.

(**Table 3**). More than half of the respondents (n = 5; 55.5%) calculate the dose for treatment based on the heaviest adult animal, generally based on visual inspection (n = 4) (**Table 3**).

The choice of anthelmintic drugs varied amongst the farms, but the most common drug class used to treat nematodes was the macrocyclic lactones (ML) 50%

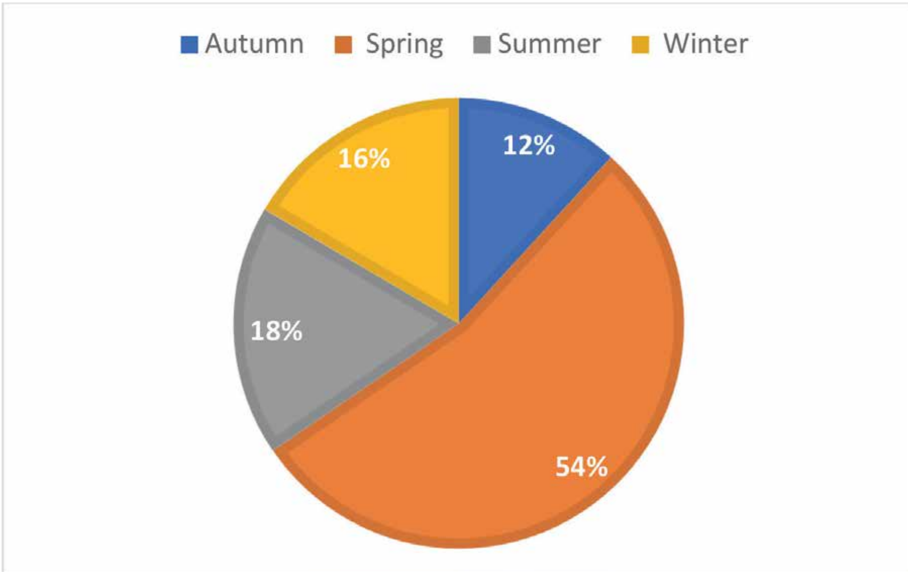

Figure 4.
The season when kidding occurred on the participating farms.

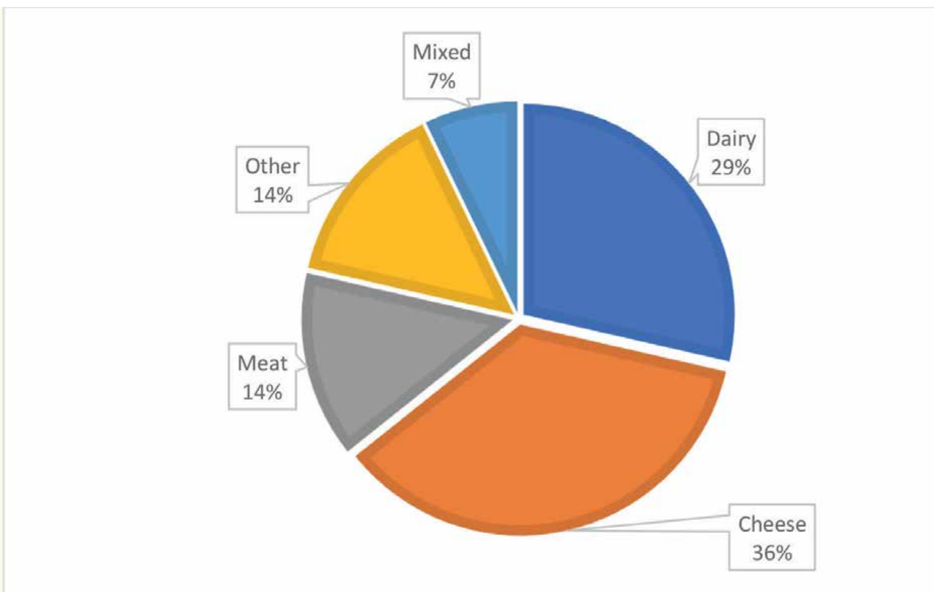

Figure 5.
Main enterprise of Irish goat farms.

(n = 3) followed by benzimidazoles (n = 2; 33%) and levamisole (n = 1; 17%). Only three respondents indicated that they treat the goats for *Fasciola hepatica* or rumen flukes. Only two respondents indicated the drug used was either benzimidazole

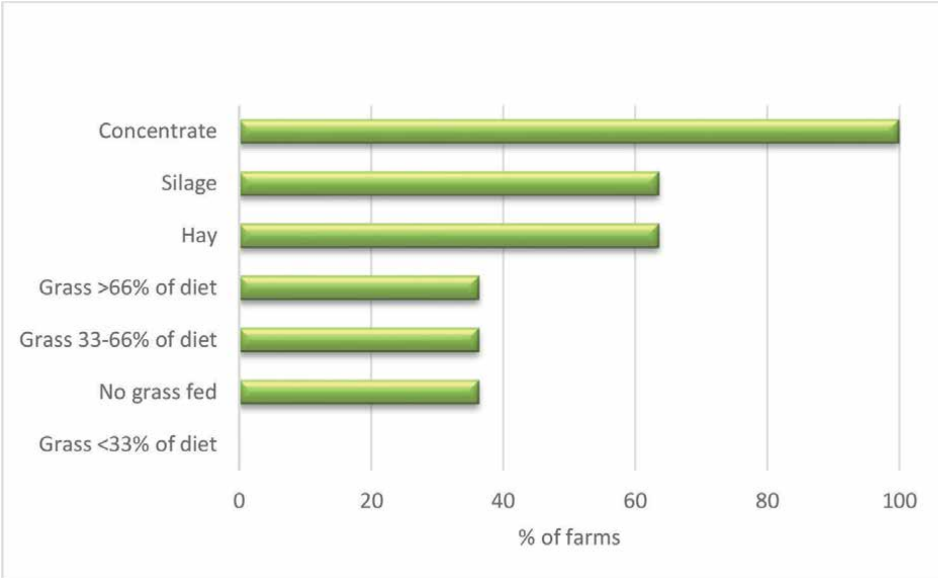

Figure 6.
Nutrition of goats on the Irish farms participating in the survey.

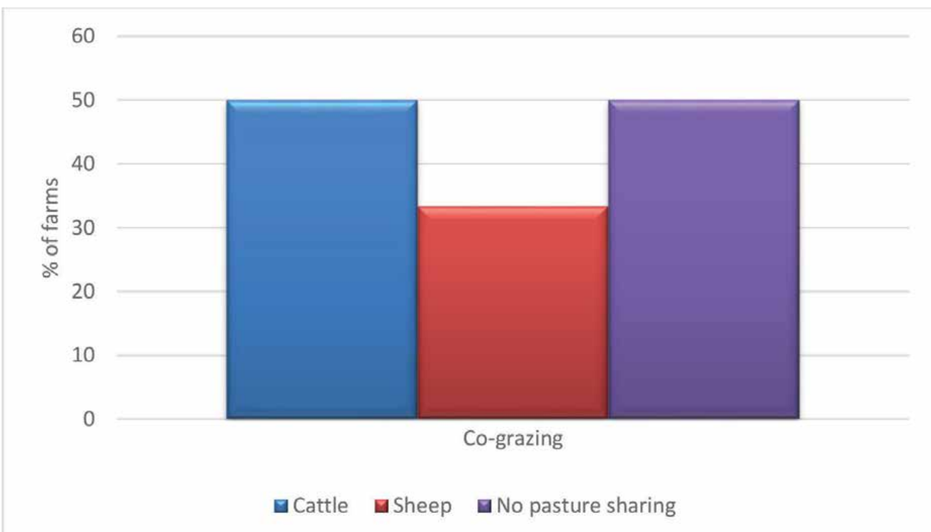

Figure 7.
Grazing practices of goat farms in Ireland.

(n = 1) or oxyclozanide (n = 1) to treat both these parasites. The actual anthelmintic dose given to goats ranged from the recommended sheep dose (n = 2; 22%) to twice the recommended sheep dose (n = 3; 33%) (**Table 3**). Past experience and veterinary

	Adults n	Kids n
Dose according to		
Treated following a set programme	3	3
Treated at sign of disease	5	4
Time when goats treated		
At any other time	2	1
Treated at dry-off	5	—
Treated at housing	4	2
Treated at sign of disease	5	4
Treated at turnout	2	1
Treated at weaning	—	2
Weight basis for dosing		
Treat to average weight (visual estimation)	4	4
Treat to heaviest (actual weight)	1	2
Treat to heaviest (visual estimation)	4	2
Anthelmintic dose compared to prescribed sheep dose		
Sheep dose	2	
1.25x sheep dose	2	
1.5x sheep dose	2	
2x sheep dose	3	
Annual treatment frequency (average)		
Nematodes	2.2	2.0
Lungworm	2.2	2.0
Liver fluke	1.8	1.5
Rumen fluke	1.0	1.0

Table 3.
Treatment practices for gastrointestinal parasites.

advice were the most common criteria used when selecting an anthelmintic product (**Figure 8**).

3.2 Gastrointestinal parasite fauna

Pooled samples from 29 adults and 12 goat kids were examined. Different nematode, trematode, cestode and protozoa parasites were detected in the pooled samples from the goats. The mean abundance and prevalence of these parasites in adult goats and kids are summarised in **Table 4**. Animals on all five farms that reported zero grazing were infected with *Eimeria* spp. and on the two farms that reported feeding cut grass to the animals were also infected with *Strongyloides*, strongyle nematodes, *Nematodirus* and *Calicophoron daubneyi* and *Fasciola hepatica*.

Figure 8.
Sources used for information on parasite control by Irish goat farmers.

4. Discussion

No survey has been done before to investigate parasite and parasite control practices in Irish goat farms. Despite the small number of survey respondents, it still provides some insights into the structure of goat farming in Irland and endoparasite control practices in general. The majority of goat farms were small enterprises with a mean flock size of 23 goats per farm, similar to the situation in the rest of the EU (https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2017)608663). The main breeds kept on farms were Saanen (n = 5; 46%) and British Alpine or Alpine crosses (n = 4; 36%), with diary and cheese production the main enterprises, as is the trend in other European countries [19]. One farm was involved in the conservation of the Old Irish goat breed (**Figure 3**). This hardy goat breed, capable of thriving in cold, harsh and damp conditions, was introduced to Ireland approximately 5000 years ago. Today it is on the brink of extinction, with only a few hundred individuals left. The Old Irish Goat Society aims to preserve the breed through the help of volunteers (https://backyardgoats.iamcountryside.com/goat-breeds/breed-profile-old-irish-goats/).

As in the rest of Europe, goat farms in this survey were divided into two systems, nearly half of farms (n = 5; 46%) followed a zero-grazing system where animals were permanently confined. Animals were fed on concentrates and other fed forages, provided directly in the feeding trough, which on two farms also included cut grass. Zero grazing allowed farmers to increase milk production [20, 21]. It is, however, important always to be vigilant for possible parasite infections, especially when the grass is fed to animals, as shown in this study where the animals on two farms that reported feeding cut grass were infected with a number of GIH. The majority of farms (n = 6; 55%) in this survey, however, practised pasture-based grazing systems with animals turned onto pasture from early spring to late autumn. Half of these farms (n = 3; 50%) also co-grazed goats with either cattle and/or sheep. This is similar to

Parasite	Mean Abundance	95% CI#	Prevalence %	Mean Abundance	95% CI	Prevalence %
		Adults			Kids	
Calicophoron daubneyi	13.45	−5.40–32.30	17.2	0		0.0
Eimeria spp.	71.59	37.98–105.20	79.3	862.5	−270.23–1995.23	100.0
Fasciola hepatica	0.21	−0.23–0.63	3.4	0		0.0
“Strongyle” eggs	421.03	80.35–761.73	69.0	223	−23.97–469.97	41.7
Lungworm larvae	6.41	−3.15–15.98	10.3	12.5	−0.14–25.14	33.3
Moniezia spp.*			6.9			16.7
Nematodirus spp.	0.62	−0.09–1.34	10.3	1.5	−0.87–3.87	16.7
Strongyloides spp.	0.21	−0.23–0.63	3.4	1	−1.20 to 3.20	8.3
Trichuris spp.	1.66	0.05–3.26	13.8	8.5	−4.24–21.24	25.0

Confidence interval.
**Only absence or presence recorded.*

Table 4.
Mean abundance and prevalence of parasites detected in pooled faecal samples of adult and goat kids in Ireland.

previous observations that co-grazing is relatively uncommon in goat farming [22, 23]. Mixed species grazing places goats at a higher risk of exposure to infective parasite stages, as goats are susceptible to many of the same parasites as sheep and cattle [2]. Grazing, rather than browsing, also puts goats at greater risk of parasite infection, as several studies have also shown that when goats are forced to graze, they are far more susceptible to infection than sheep [2]. Co-grazing may also play an important role in the transfer of anthelmintic-resistant helminths between host species. This is supported by the detection of early cases of moxidectin and monepantel-resistant nematodes from goats in Australia and New Zealand [24]. Anthelmintic resistance to the three commonly used drug classes BZ, levamisole, and ML is widespread in Irish sheep [11, 13].

Anthelmintics were used on all farms to control gastrointestinal parasites in both adult goats and goat kids, even on the farms that reported following a zero-grazing regiment. The annual treatment frequency for nematodes ranged from 1 to 4 for adults and 1–3 for kids. This is lower than the four or more treatments given to lambs by Irish sheep farmers [25]. It is also lower than the treatment frequencies reported for goats in Europe [23, 26–28] and New Zealand [29–31]. The development of anthelmintic resistance has been associated with the frequency of anthelmintic administration, as the selection pressure for resistance increases when the interval between treatments decreases [32, 33]. At least the lower treatment frequency reported in this survey should result in more worms in refugia and therefore put less selection pressure for anthelmintic resistance, but as discussed later, other management factors implement may select for resistance.

ML was the most frequently used anthelmintic class (n = 3; 50%), which was also the trend reported in many other countries [1, 34–36]. The majority of farmers (8/11; 73%) calculate dose rates based on visual estimation of weight. Similar trends was also reported in other surveys in Europe [23, 27].

With regard to the specific anthelmintic dose rate used in goats, 22% of farms used the prescribed sheep dose, three farms (22%) used twice the recommended sheep dose, and the remaining used between 1.25x and 1.5x the sheep dose. Using an accurate dose to treat helminths is essential to ensure good parasite control efficacy. Reliance on the estimation of weights using visual estimation has been shown to lead to underdosing and increases the selection pressure for resistance in sheep [22, 32, 33, 37]. Accurate dose calculation is especially important in goats since it has been known for more than 30 years that the pharmacokinetics of anthelmintic drugs in goats is different to that of sheep, and goats require higher dose rates to maintain the same plasma concentration and half-life [6, 8, 9, 38, 39]. This is further complicated because, in most countries, including Ireland, anthelmintic drugs are not specifically registered for use in goats. The only exception is eprinomectin which is licenced for use in goats in Ireland in both injectable and pour-on formulations; however, no distinction is made between sheep and goat doses (https://www.hpra.ie/). Only six of the respondents expressed an opinion on whether or not the anthelmintic treatments work as well as it did in previous years, with two-thirds (66%) believed that drugs are less efficacious than before. However, a FECRT was never performed on any of the farms. Goat farmers mostly rely on past experience and veterinary advice when selecting a drug which is similar to sheep farmers in Ireland and the UK [25, 40] and goat farmers in Denmark [23].

The results indicated that 100% of goats were infected with a variety gastrointestinal and lungworm parasite species, also commonly recorded in previous surveys of sheep in Ireland [11, 41]. *Eimeria* spp. was the most prevalent parasite detected in 100% and 79% of kids and adult goats, respectively. A high prevalence of *Eimeria* spp. infection has also been reported in Lithuania [42] and Italy [28, 43]. Infection with strongyle nematodes was also highlighted as prevalent in the goats (69% adult goats; 42% goat kids) in this study, similar to what was recorded in Italy [28, 36] and Lithuania [44]. Parasitism with these endoparasites is normally associated with significant production losses, with a decrease in milk yield and quality, reduced growth rate, discarded organs at slaughter and death [36, 45, 46].

This survey also found lungworm infection in 10% of farms in adult goats and 33% of goat kids. A higher lungworm prevalence was found in dairy goats in France (95.5%) [47], northern Italy (44–78%) [36], and Czech Republic (93.1%) [48]; however, lower infection was detected in Germany (35.1%) [49] and Norway (31.2%) [50]. In general, infection with lungworm parasites seldom causes clinical disease in sheep and goats [51, 52].

The prevalence of *Strongyloides papillosus* (8.3% and 3.4%, goat kids and adults, respectively) was lower than found in other surveys, which generally vary between age groups, management systems, areas and climates (12.8%) [53], Slovakia (14.05%) [54] and Somalia (25.58%) [55]. *Strongyloides* infections are generally only sporadically associated with clinical signs in herbivores [56]. An experimental infection with *S. papillosus* in goats showed clinical signs, including transient diarrhoea, elongated faecal pellets terminally, dehydration, anorexia and anaemia [57]. *Nematodirus battus* prevalence was also generally low (10.3 & 16.7% adult goats and kids, respectively), but still an interesting finding considering that the faecal samples were collected in late summer (August–October). Nematodirosis is generally regarded as a disease of young lambs in the spring and adult animals play a negligible role in its epidemiology [58]. However, recent studies have found that substantial proportions of *Nematodirus* eggs will hatch without the need for chilling [59, 60]. This is evidenced by recent reports of outbreaks of nematodirosis later in the grazing season (or indeed in the autumn) in older lambs [61, 62]. The prevalence of *Trichuris* spp. of 10.3% and 25% in adult goats and goat kids, respectively, was higher than reported in other surveys, which range from 0.7–17% [53, 54, 63]. The overall low prevalence reported in the literature with this parasite may be related to difficulty in detecting light infection of this nematode in faecal flotation techniques [64]. This parasite of the cecum is very seldom associated with clinical disease in ruminants [65, 66].

Trematode infection ranged from 3% for *F. hepatica* and 17% for *Calicophoron* spp. in adult goats only. The low *Fasciola* prevalence was surprising as it is quite common in sheep and cattle throughout Ireland [67, 68] and is responsible for considerable production losses across Europe [69, 70]. There are only a limited number of studies that reported rumen fluke infections in European goats [71]; however, *Calicophoron* spp. is emerging as a prominent parasite in cattle and sheep in many parts of Europe, including Ireland [71–76]. A decline in *Fasciola* prevalence has been noted in a previous survey in Ireland [73]. The immature stages of *Calicophoron* can cause severe disease and have even been associated with outbreaks in cattle and sheep [77–79], while the adult ruminal phase is usually clinically inapparent.

5. Conclusion

This is the first survey of goat parasite control and GIH infection goats in Ireland. The present study does have some limitations, (i) only a very small number of farms were surveyed; and (ii) since the farmers volunteered participation, that could potentially have biased the response as the farmers probably had a particular interest in parasites; (iii) only pooled samples were used to estimate prevalence abundance. However, the authors do believe that it still provides some valuable information on general farming practices and helminth prevalence. Overall, the present results highlight several animal husbandry and parasite control practices on goat farms that may favour the spread or development of anthelmintic resistance in nematode populations. There is a clear need to improve the communication of information on new techniques and methods of parasite control to the farmers. The results also point to the need to develop new commercial drugs for the goat industry in order to avoid the excessive dependence on one class of anthelmintics, with probable consequences on long-term efficacy.

Further studies on caprine gastrointestinal parasites using other techniques, for instance, molecular tools, would be indicated. Additionally, future studies should be more longitudinal in nature to study the effect of season, grazing patterns and goats breeds on the prevalence of gastrointestinal parasites.

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Conflict of interest

The authors declare no conflict of interest.

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Chapter 9

Prevalence of Trypanosomosis in Ruminants in Rivers State and Abia State, Nigeria and the Challenges of Trypanosomosis Control in Goat Production

Clara A.N. Akpan

Abstract

Trypanosomosis is one of the major diseases hindering livestock production in tropical Africa. The disease negatively impacts food production and economic growth in sub-Saharan Africa. African animal trypanosomosis is a debilitating and often fatal disease of animals, caused by infection with pathogenic protozoan parasites of the genus '*Trypanosoma*'. A recent prevalence study for the infection in ruminants reared in two Southern states of Nigeria (Rivers and Abia) gave zero by the wet mount and buffy coat methods which only suggests low prevalence and may not mean that the infection has been eliminated in the country. More sensitive methods may detect low prevalence. It also suggests that common breeds of ruminants in the area may be genetically resistant to the infection or that they have acquired resistance. Relapse to susceptibility is still possible. So, prophylactic medications and other methods of control for the infection are still necessary for the area.

Keywords: prevalence, trypanosomosis, Nigeria, challenges, control

1. Introduction

Livestock diseases reduce agricultural output by about 30% in developing countries including Nigeria [1]. These diseases are endemic including fly-borne diseases like trypanosomosis, tick-borne diseases like babesiosis as well as helminthosis; all of which increase morbidity and mortality, reducing production and subsequently leading to hunger and poverty. Trypanosomosis is a debilitating and often fatal disease of man and animals, caused by infection with the pathogenic protozoan parasites of the genus *Trypanosoma* [2–5]. It is an economically significant disease affecting livestock production in Nigeria and causing significant losses ranging from a decrease in production to death [6, 7]. The disease is characterized by anemia, parasitemia, fever, loss of condition, reduced productivity and frequently high mortality which among other factors limit the pace of development in tropical

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Africa. Trypanosomes are extracellular parasites that cause persistent infection of the blood (and/or body fluids) and induce immunosuppression [8]. Trypanosomes are widely distributed due to the abundant presence of its biological vector (tsetse, *Glossina* spp) [9] which covers about 80% of Nigeria's land mass; and mechanical transmission vectors, which are biting flies, like *Tabanids* (horse flies), *Stomoxys* (stable flies) and vampire bats [10]. The severity of disease caused by trypanosomes depends on the species and strain of the infecting trypanosomes [11], with *T. congolense* having a more severe impact than the other species, on ruminants' health and production [12]. Infections with *Trypanosoma brucei, Trypanosoma congolense, Typanosoma vivax* and *Trypanosoma evansi* have been reported in goats [13, 14]. Concurrent infections can occur with more than one species of trypanosome [15].

Control of African Animal Trypanosomosis (AAT) includes the use of trypanotolerant breeds of livestock [16, 17], vector control [18], chemotherapeutic and chemoprophylactic agents [19] or a combination of the methods according to specific conditions of an area [20]. However, control of animal trypanosomoses relies primarily on the use of insecticides or traps to control the vector (especially in the case of tsetse-transmitted trypanosomes) and on the use of trypanocides to control the parasite [21]. The use of trypanocidal drugs for trypanosomes parasite control represents the main intervention tool in most poor rural endemic areas since vector control can be expensive when used on a large scale and is not always sustainable or effective [22, 23].

Drug resistance, relapse of infections and toxicity of trypanocidal drugs are major challenges encountered in parasite control (treatment) of trypanosomosis.

Most of trypanocides are expensive and/or toxic [24] and have the tendency to elicit drug resistance [25, 26]. Some of the trypanocidal drug-induced side effects can be serious and even life-threatening [27]. Relapse of infection, sometimes observed after treatment of trypanosomosis, has been attributed to the resurgence of parasites into blood and body fluids after the invasion of the brain tissue by the tissue-invasive *Trypanosoma vivax* and *Trypanosoma brucei* group parasites [28–30] which are inaccessible to trypanocidal drugs due to presence of a blood-brain barrier. Reports have shown that some strains of *Trypanosoma brucei* group of trypanosomes invade body tissues as early as four hours to four days post-infection [31, 32]. Apart from causing disease, trypanosomes are also responsible for producing a state of severe immunosuppression, which renders the infected host more susceptible to secondary infections and produces a poor immune response to bacterial and viral vaccines [8]. This is due to the reduction of their ability to mount protective immune responses against invading parasites [33]. Immunosuppression is a major obstacle to sustainable livestock production [34] and food security. The significance of immunosuppression is appreciated more in endemic areas where herd immunity against serious epizootic diseases depends on massive vaccination campaigns [35].

There is limited information on the prevalence of trypanosomosis in the southern part of Nigeria. A prevalence rate of 17.10% of ruminant trypanosomosis was recorded in a survey of livestock diseases from September 2002 to August 2003 in Enugu State, South-East Nigeria [36]. In a part of Abia State, a low prevalence rate of 1.9% was recorded in ruminants with goats having a prevalence rate of 1.2% for trypanosomosis [37]. The low prevalence rate of trypanosomosis in small ruminants compared to cattle, in Nigeria, has been attributed to trypanotolerant breeds being the majority among small ruminants [7, 38, 39]. The prevalence of trypanosomes in animals could be affected by several factors such as availability of reservoir hosts, seasonal factors, altitude, fly density and behavior, sensitivity of diagnostic techniques, stage of infection, method of sampling, conflict and other human activities [40–42].

A zero prevalence of trypanosomosis in goats was recorded recently in both Rivers and Abia States, Nigeria [43], agreeing with reports that goats are resistant to trypanosomosis [44]; however, several other studies on the prevalence of trypanosomosis in goats revealed that goats acquire natural infection resulting in economic losses [45–47]. These losses include a reduction in milk production, weight gain, reproduction and eventually death of the affected animals [48]. Goats that survive the infection become reservoirs of the parasite and endanger humans and other domestic animals [6].

The disease leads to a reduction of animal protein [49] thereby promoting food insecurity [50] and contributing greatly to underdevelopment through poverty and hunger [5, 51].

Goat production is a great source of income for commercial farmers. Goats also serve to improve the economy of peasant farmers who may not be able to keep large ruminants like cattle. They provide meat, milk, skin and manure. In Nigeria, goats can be used for important religious and social activities besides serving as cash reserves and a form of savings for rural populations or households. They serve as a source of income in times of stress, during drought and agricultural crop failure [52–54].

There is a paucity of information on the prevalence of trypanosomosis in the southern part of Nigeria, as the majority of studies on trypanosome prevalence were conducted in the northern and central parts of Nigeria. Hence, this study on the prevalence of trypanosomosis in Rivers and Abia States Nigeria, which are both in the southern part of the country, was aimed at investigating the current prevalence of trypanosomosis in cattle, sheep and goat in Rivers (South-South) and Abia (South-East) states, Nigeria.

2. Materials and methods

2.1 Study area

This study was conducted between July and October 2018 in Ahoada West LGA, Ahoada East LGA and Ikwere LGA of Rivers State as well as Umunneochi LGA and Ikwuano LGA of Abia State. Animals sampled belonged to individuals.

Geographically, Abia State occupies about 6320 square kilometers of land area, with a population of about 4,112,230 and a population density of 650/km^2. It lies between latitude 5.251°N–5.417°N and longitude 7.30°E–7.500°E, altitude of 244–305 m above sea level. It is a low-lying tropical rainforest. The southern portion gets heavy rainfall of about 2400 mm per year which is especially, intense between the months of April through October [55].

Rivers state occupies a total land area of 11,077 square kilometers with a population of about 5,198,716 and a population density of 635.89 per square kilometer. It lies between latitude 4°45^{1}N–4.750°N and longitude 6°50^{1}E–6.833°E. Its annual mean temperature ranges from 25°C to 28°C. Total annual rainfall decreases from about 4700 mm on the coast to about 1700 mm in the extreme north.

2.2 Sample size

The sample size was determined using the formula outlined by [56] and expected/anticipated prevalence of 3.7% for cattle; 1.1% for sheep and 1.2% for goat [17].

$$N = \left(Z^2 pq\right) / L^2 \quad (1)$$

Where:

p = anticipated/expected prevalence from similar study = [3.7% for cattle; 1.1% for sheep and 1.2% for goat, Z = 1.96; q = 1-p; N = sample size; L = allowable error (5%).

Fifty (50) cattle, twenty-five (25) sheep and twenty-five (25) goats were sampled in each of Rivers and Abia states, giving a total of 100 adult cattle (N'dama, Muturu, white Fulani and Red Bororo breeds), 50 adult sheep (WAD and Yankasa) and 50 adult goats (WAD and Sokoto red) of both sexes.

2.3 Study animals

The study was carried out on 100 cattle of breeds: 29 N'dama, 42 Muturu, 17 White Fulani and 12 Red Bororo; 50 sheep of breeds: 32 West African Dwarf (WAD) and 18 Yankasa; and 50 goats of breeds: 36 West African Dwarf (WAD) and 14 Sokoto Red selected by random sampling methods. Three herds of cattle, sheep and goats were sampled in three different locations in each of the states. The age of the animals was estimated, when not known by their owner, on the basis of the dentition, in which animals under 1 year were considered as young animals. Adult animals (above 1 year for sheep and goat; above 2 years for cattle), were sampled.

2.4 Sample collection

Blood samples were collected from the jugular vein of each sampled animal. Two (2) ml of blood was collected from each animal and put into a container with EDTA. The containers were gently rocked to homogeneously mix the blood with the anticoagulant (EDTA) in order to prevent clotting. The blood samples were either examined immediately or kept cool in a flask containing ice packs until examined microscopically within 4 hours, by wet mount and buffy coat methods.

2.5 Parasitological examination

The parasitological examination was done in the laboratory using the wet blood film [57] and microhematocrit buffy-coat methods [57].

2.5.1 Wet blood film examination

A blood film was made by placing a drop of blood on a clean glass slide which was then covered carefully with a clean cover slip so that the blood spreads evenly. The slide was placed on a microscope and the film was viewed systematically for movement of trypanosomes with x40 objective lens [58].

2.5.2 Micro-haematocrit buffy coat microscopy

A capillary tube was nearly filled (about ¾) with a blood sample and centrifuged at 2000 g for 5 min. The capillary tube was cut about 1 mm below (to include the uppermost layer of RBC) and 3 mm above (to include some plasma) the buffy coat layer. The content was gently expressed onto a slide using a micro-hematocrit capillary tube holder, mixed and covered with a cover slip. The preparation was then examined under a microscope with the ×40 objective lens [57].

3. Result

Out of the total of 100 cattle, 50 sheep and 50 goats sampled in the two states (Abia and Rivers), no positive sample was gotten. The species, number, sex and breed of animals sampled in the survey are shown in **Table 1**.

4. Discussion

The result of the survey seems to indicate the absence of trypanosome infection or zero prevalence of trypanosome infection in the studied areas. This is in agreement with the report of [59] in which N'dama and Muturu breeds among other breeds of cattle investigated in Keffi, Nassarawa State, were not infested with trypanosomes.

The result is also, in line with the report of [60] in which none of the Tsetse dissected in his work in Bassa, Plateau State was positive for trypanosomes thus suggesting a low prevalence of trypanosomes in ruminants in that area. A low prevalence rate of 1.9% in ruminants with goats having a prevalence rate of 1.2% in some parts of Abia State, has been reported [17].

There is a dearth of information on ruminant trypanosomosis in the areas studied (South-East and South-South, Nigeria), hence a lack of data for comparison.

The absence of infection or zero prevalence as observed in the study suggests a very low infection rate attributable to a decrease in the population of tsetse and other biting flies as a result of environmental, weather and anthropological changes. Since the survey was conducted on animals owned by individuals, it is also possible that farmers inject their animals with trypanocidal drugs and also use insecticide sprays to minimize the population of biting flies. The rise in human population and consequent increase in human activities causing significant changes in the availability of suitable habitats and hosts that potentially ensure tsetse survival and sustenance in a given location may also have occurred [61]. In addition, the expansion of veterinary services up to peasant associations and deforestation for crop cultivation and settlement might be a reason.

The zero prevalence observed in the area could also be due to the inadequacy of the parasite detection methods employed. The micro-hematocrit-buffy coat method used for diagnosis is still regarded as a good parasitological technique for quick detection of the parasite, allowing for quick and clear visualization [62], though it has been reported to be relatively insensitive as it fails to detect 66% of infected animals compared to molecular diagnostic techniques and serological diagnostic methods [63]. More so, trypanosome organisms are most likely to be found in the blood during the initial or early stages of the infection. They are less likely to be detected in chronically ill animals and may never be detected in healthy carriers [64].

Low prevalence or absence of infection may also relate to the reported resistance of indigenous ruminants to trypanosomes infections [65–67]. There are reports of trypanotolerance involving N'dama and Muturu breeds of cattle [68, 69], which form the majority of the sampled animals. The zero trypanosomes in Red Bororo observed in this study also agree with the report of [60] in Bassa LGA of Plateau State. This trypanotolerance could be largely due to innate resistance and natural genetic

Animal species	Cattle								Sheep				Goat			
Breed	**N'dama**		**Muturu**		**White Fulani**		**Red Bororo**		**WAD**		**Yankasa**		**WAD**		**Sokoto Red**	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Number	22	7	30	12	11	6	10	2	20	12	11	7	20	16	8	6
Total No	29		42		17		12		32		18		36		14	

Table 1.
Number, sex and breed of ruminants sampled for trypanosomes in Rivers and Abia states of Nigeria.

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manipulation over time, to adapt to tsetse bites and partly due to their coat color that may serve as camouflage. Some trypanotolerant breeds tend to self-cure and eliminate the organism. Others may remain persistently infected but maintain productivity and show few or no signs of illness [64]. It might also be due to their hairy tail-end, used in warding off tsetse. More so, animals in the southern part of Nigeria are more or less intensively managed; extensive management of livestock has been reported to be a risk factor for trypanosomoses with higher prevalence rates compared with intensively managed animals [70].

Implications of the discovery include that Abia and Rivers States are good for sustainable livestock (ruminant) production since trypanosomosis identified as a serious constraint to livestock production and economic development in Nigeria appears to have become insignificant in the area. This, however, does not mean the infection has been eliminated. If more sensitive methods are used for purely epidemiologic studies low prevalence may be recorded. So, there is still a need to search for better and cheaper methods for prophylaxis and treatment of the disease.

5. Conclusions

Goat trypanosomosis, though of low prevalence in the southern part of Nigeria, could be of serious economic impact and public health importance, if neglected and uncontrolled.

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Conflict of interest

The author declares no conflicts of interest.

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Chapter 10

Use of Eucalyptus Wood Vinegar as Antiseptic in Goats

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Abstract

The use of wood vinegar *Eucalyptus urograndis* is used with antiparasitic, antibacterial, antifungal, but its action in combination with glycerin or matodextrin has not been demonstrated. In this way, we will inform this chapter this question, as well as the cytotoxicity in cells of the mammary gland. It was checked in the laboratory and in animals. It has been verified that the action with glycerin is better than the use with maltodextrin and that there is no cytoxicity in the mammary gland of lactating animals.

Keywords: wood vinegar, maltodextrin, bacteria, milk, goats

1. Introduction

The term pyroligneous comes from "pyrolysis", a process that uses energy biomass for the production of the wood vinegar. It needs to go through a process of combustion. This process is called pyrolysis, a term for thermal decomposition of materials containing carbon in the absence of oxygen, in this process coal is obtained greenhouse gases with a negative environmental impact. This impact can be decreased if the oven is adapted to collect a condensable fraction, also known wood vinegar the remaining part is called non-condensable gases (CNG) [1]. This process is carried out with several plants, as Eucalyptus. This originates in Australia. Its first plantings were in Europe, Asia and Africa in the early eighteenth century, arriving in Brazil a century later [2]. The genus Eucalyptus sp. is the most planted in the whole country. The plant has rapid growth, high density and productivity, its use includes, fence constructions, pulp extraction for paper production, bioproducts, animal feed [3]. Several organic compounds are described are acetic acid, formic acid, propionic acid, methanol,

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maltol, ether, methyl alcohol, alcohols, acetaldehydes, acetone, ketone, phenols, guayacol, furan derivatives, and pyran, esters, cresol, derived from carbohydrates and nitrogen compounds [4]. Research on the use of pyroligneous acid (PA) against gram-positive, gram-negative and yeasts was confirmed in vitro [5]. Another study analyzed the effect in vivo of wood vinegar as a cutaneous antiseptic in ruminants [6] and there were found a lower bacterial count. Other studies have been observed as insecticides [3, 7].

2. Methodogy

2.1 Production of *Eucalyptus* wood vinegar

Wood samples from *Eucalyptus urophylla x Eucalyptus* grandis hybrid (clone I144) were collected from 8-year-old plantations in the experimental area of the Agricultural Sciences Unit, Universidade Federal do Rio Grande do Norte (05° 51′30″S and 35° 21′ 14″ W), municipality of Macaíba, Rio Grande do Norte State, Brazil. One hundred 3.0 cm-thickness wood disks were collected by following the procedures established by [8] and divided into four wedges each. Samples were oven-dried (Sterilifer, model SX cr/80, São Paulo, Brazil).at 103 + 2°C for 48 hours until reaching absolute dryness.

For the carbonization runs, the dry samples of each material were placed, separately, in a steel container inside a laboratory muffle equipped with a condensation apparatus to collect the total pyrolysis liquids. The condensation device was water-cooled aiming to maintain its temperature around 25–30°C, providing conditions for the condensation of vapors from the carbonization bed. For each type of woody material, 15 carbonization runs were carried out with about 500 g of plant material each. After each was concluded, the liquid products were mixed to make at the end of the experiment one composite sample of vinegar from each woody material. The carbonization process was carried out from the ambient temperature until reaching 450°C, with a heating rate of 0.7°C min 1, totalizing 8 hours. Composite samples of eucalyptus and bamboo vinegar were distilled under a 20-mmHg vacuum until the range of 100–103°C to remove tar and heavy oils from them. After the distillation, the resulting products were stored in amber bottles, previously sanitized with boiling water, and stored under refrigeration at 6°C for further procedures and experiments.

2.2 Cytotoxicity

Efficient protocols that ensure the verification of the cytotoxic potential of components of natural origin are essential for the proper use of substances for medicinal and/or therapeutic purpose. In general, the culture of animal cells allows obtaining information with greater productivity and speed [9]. In this sense, cytotoxicity can be conceptualized as the ability of a substance to inhibit the proliferative activity of cells, or cause damage to cells, resulting in cell death [10]. Since different substances, whether of endogenous or exogenous origin, can reduce cell proliferation, drugs developed in human and/or veterinary medicine must be previously tested.

A series of *in vitro* assays can be proposed to evaluate the toxicity of substances in cells [11, 12]. The most widely used assays involve the use of microscopy and spectrophotometry, relating assessments on cellular morphology, viability and metabolism, which mirror the proliferative activity of cells. In cytotoxicity assays of the eucalyptus wood vinegar in cultured goat cells [6], the analyzes have been those related to morphological evaluation by brightfield microscopy, viability by the cell membrane integrity assay using trypan blue and metabolic activity by the -(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. For all analyses, the conditions of isolation and *in vitro* culture of the cells are fundamental for the accuracy of the results.

2.2.1 Step by step in the elaboration of a cytotoxicity assay in goat cells

In general, an *in vitro* cytotoxicity protocol involves the stages of isolation and *in vitro* characterization of the cells to be evaluated, and applications of cell analysis methodologies [13]. In cytotoxicity assays of the eucalyptus wood vinegar in cultured goat cells, initially, goat mammary gland skin tissues are aseptically collected and transported to the laboratory in Dulbecco's modified minimal essential medium (DMEM) plus 10% fetal bovine serum (FBS), and 2% antibiotic-antimycotic solution at 4°C for up to 1 h. In the laboratory, these tissues are fragmented into 9.0 mm^3 (3 × 3 × 1 mm), washed and cultured in pretri dishes containing culture medium [DMEM, 10% FBS and 2 of 2% antibiotic-antimycotic solution] at 38.5°C and 5% CO_2 until cell detachment. This cell detachment occurs in up to 7 days, where the first cell subculture is carried out. After three subcultures, cells are cryopreserved or evaluated for cytotoxicity assays.

For the *in vitro* cytotoxicity assays, cells are evaluated before and after incubation with the eucalyptus wood vinegar, which has been for a period of 10 min [6]. Thus, in morphological analyses, cells are evaluated using an inverted microscope and the characteristics of cytoplasms with elongations, evident nucleus are evaluated. For cell viability, the trypan blue assay consists of an analysis to evaluate the integrity of the membrane. Briefly, after incubation with 0.4% trypan blue, cells in blue (broken membrane) and colorless (membrane intact) are counted in a hematocytometer and the viability rate calculated [14, 15].

Finally, the metabolic assay is performed using the MTT reagent and consists of a colorimetric assay for assessing cell metabolic activity [16]. It is based on the conversion of MTT into formazan crystals, which is associated with mitochondrial and cytoplasmic cellular functioning. Briefly, the assay is based on the metabolic reduction of MTT by dehydrogenases linked to NADH and NADPH that cleaves the tetrazolium salt to formazan crystals by metabolically active cells, reflecting in the number of viable cells present. This by-product has a dark color, which can be measured in a spectrophotometer. The absorbance result is calculated based on metabolism, because the darker the cell residue, the more viable cells metabolically produced it and the lower the cytotoxicity to metabolism promoted by the substance tested.

All *in vitro* cytotoxicity assays have advantages and limitations and the associated use of several tests guarantees safe results (**Table 1**). Cell health can be checked by a variety of methods [17] and the choice of a good cytotoxicity assay depends on the specific issues of each substance to be tested, relating cell type conditions and *in vitro* culture conditions [10].

Other methodologies can be cited to evaluate the cytotoxicity of extracts, such as apoptosis assays by flow cytometry, and comet assays. In the first assay, cells are labeled with fluorescent probes, such as annexin and propidium iodide, and evaluated by flow cytometry [15]. In the second assay, cultured cells are treated with the alkaline comet method, and evaluated by fluorescence microscopy [18].

In vitro **analyzes**	**Advantages**	**Limitations**
Morphological evaluation	• Easy execution when compared to other *in vitro* analyses • No need for pretreatment on cells	• Subjective analysis method • Use of inverted analysis microscopy
Viability by the cell membrane integrity assay	• Low cost method • Easy execution when compared to metabolic activity	• Cells can be dead without necessarily having their membrane broken • Cells with small pores may have dye penetration and not be unviable
Metabolic activity	• Assay widely used to assess proliferative activity • Accurate assessment of proliferative activity	• Use of reagents to assess metabolic activity • Need for spectrophotometer within the wavelength.

Table 1.
Advantages and limitations of the main analyzes used in in vitro toxicity tests.

2.3 Action in vivo

Research on the action of the wood vinegar associated with matodextrin and glycerin in vivo was carried out on the dairy goat property in the Independência Mossoró settlement/RN. The animals were randomly selected, separated into stalls, and daily subjected to antisepsis for 21 consecutive days. The experiment was authorized by opinion CEUA 02/2021. Twenty animals were divided into four distinct groups (A), (B) (C) and (D). Group A belongs to animals that received daily application of a conventional antiseptic (2% iodine tincture) - this being the positive control group. In the second group B was the animals that were treated daily with sterile distilled water, this being the negative control group. Test group C was submitted to treatment with the eucalyptus wood vinegar with maltodextrin and without glycerin and D was group with wood vinegar associated with glycerin.

The teat of each animal was immersed in the mentioned solutions, daily, once a day, for a period of 28 days. Four samples were collected with an interval of 7 days, being 0, 7, 14 21 and 28 days with sterile swab on the lateral part of the teat in an area of 1 cm^2.

After applying the product on the surface, 10 minutes were timed, referring to the time of action. After the product's time of action, a sterile swab was used to pass over the entire surface of the teat, this swab was then refrigerated at 8°C for further processing and serial dilution.

From the collected swab, it was processed; a serial dilution of the swab collected from the surface of the mammary gland roof was made, and an aliquot of each dilution of 10^{-1}, 10^{-2} and 10^{-3} was plated. Then, 1 ml of each dilution was distributed in Petri dishes containing Agar Plate Count (PCA) and subsequently taken to the bacteriological oven for 24 hours at a temperature ranging from 37 + − 0.5°C, to promote growth and development bacterian. After the time in the greenhouse, they were removed and counted. The numbers of viable colony-forming units, obeying the lower limit of 30 and the upper limit of 300 colonies [19].

After the isolation of the bacteria found in the negative control group, these were cultivated in BHI broth for 24 hours at 37° C until the log phase for approximately

24 to 48 hours, adjusted by the Macfarland scale. The microorganisms were identified through cytology and biochemical tests [20].

3. Results and discussion

3.1 Main results of the eucalyptus wood vinegar in goat cells

In cells isolated from the mammary gland of adult goats [6], the *in vitro* toxicity of 20% of the eucalyptus wood vinegar was evaluated from a compilation of three assays [morphology, viability and metabolic activity]. Comparisons were made with a group without the presence of any antiseptic substance and another group of cells incubated with 2% iodine solution, a commercial antiseptic currently used in many productive sectors. All these assays correspond to what we conceptualize as cell viability, through proliferative analysis. Thus, in goat cells, the eucalyptus wood vinegar did not affect cell morphology, being evidenced in all groups of cells with healthy morphology, with evident cytoplasm and nucleus and with evident cytoplasmic prolongations.

Interestingly, the viability assessed by the membrane integrity assay showed no difference between the groups, with viability values ranging from 57.6 to 88.6%. Nevertheless, when the metabolic activity was evaluated, both antiseptics (iodine solution and eucalyptus wood vinegar) caused a reduction of this parameter with values ranging from 31.8 to 47.6%, while cells not incubated with any substance presented values of 100%. Probably, the chemical composition of eucalyptus wood vinegar may be responsible for this reduction in metabolic rate; although it was similar to the values found in the iodine solution [6]. Moreover, cytotoxicity assays do not have the same principle [15], that is, while morphology assesses the surface conditions of cells, and trypan blue assesses cell membrane integrity, the MTT assay assesses metabolic activity associated with mitochondrial function, justifying thus differential responses of the eucalyptus wood vinegar on the cells.

3.2 Action *in vivo* of Eucalyptus wood vinegar associated a maltodextrin and glycerin

Lack of hygiene may result in loss of quality of milk matter, as well as its derivatives, leading to financial losses due to non-marketing of contaminated milk. Hygiene practices during and after milking considerably control cases of mastitis in the herd, contributing to standardized milk production with superior quality. Currently, the chemical products most used as antiseptics for the teats of dairy cows, before and after milking, are products based on 0.5% iodine and chlorhexidine [21].

In recent years, research focused on the use of medicinal plants has achieved excellent results by the scientific community in alternative and complementary treatment in veterinary medicine, both through the use of fresh vegetables or plant extracts and the use of herbal medicines administered in a complementary way or as inputs [22]. Thus, the objective of the present work is to prove the antiseptic action of the wood vinegar of eucalyptus sp. at 1% and also associated with maltodextrin or glycerin in Saanen goats with dairy ability as an alternative to the use of industrial antiseptics.

3.2.1 Bacteria count according to the action of wood vinegar

The data obtained in this research reveal that the treatment using vinegar wood associate a glycerin after iodine 2%. (**Table 2**). The results regarding

Groups	Day 0	Day 7	Day 14	Day 21	Day 28
Vinegar wood associated a glycerin	2.58	3.50	3.91	3.61	3.70
Vinegar wood associated a maltodextrin	5.39	4.86	2.59	2.40	5.34
Iodine 2%	2.53	3.42	2.59	2.40	3.19
Water Distilled	2.26	4.41	5.22	4.73	4.71

Table 2.
Number of bacteria (log 10) from the teats of animals that received natural and conventional antiseptics.

vinegar wood associated a glycerin were better than the data that reveal the use of vinegar wood associated with maltodextrin. The best results regarding glycerin are justified due to the better fixation performed by this compound [23]. The glycerin potentiates the action wood vinegar of Eucalyptus and states that the presence of phenolic compounds that exist mainly as simple phenols, such as phenol, cresols and 1,2-benzenediol [6].

When is using the bacteria count according to the action of associated with maltodextrin had no antibacterial effect on the post dipping of goat teats. It is s suggested that maltodextrin has provided nutritional conditions for bacteria. This statement can justificated where studies show that there are important proteins that bind to maltodextrin and are ideal for the colonization of pathogenic bacteria's [24]. Noting that the number of bacteria was higher than the negative control.

The antimicrobial effects of these phenolic compounds are mainly due to the chemical structure of these phenols, which allows them to act as proton exchangers that can lower the pH gradient across the cytoplasmic membrane, causing microbial cell death [25], it was not observed when wood vinegar associated maltodextrin.

The increase in the number of bacteria when maltodextrin is used may be associated with the absence of active principles such as guaiacol [5]. This is derivatives along with other phenols and furfural in the bacteria count according to the action of may explain the antibacterial and antifungal activities.

3.3 Influence of wood vinegar on goat milk

Does the wood vinegar used in post-dipping of dairy goats as a preventive measure for mastitis cause some interference in milk? This study in particular opens an interesting perspective for its use in processes involving the production of food intended for human food. As a measure of food safety, all food produced must present nutritional quality, which involves the microbiological quality that needs to be in accordance with current legislation, in this case, normative instruction No. 37 of October 31, 2000 [26].

According to this legislation, there are some practices, care and mandatory processes to minimize possible health-related risks. These risks may be of chemical, physical and biological origin. For goat's milk, one of the main risks presented is organic, since food because it is one of the most complete, has physical-chemical properties conducive to the development of deteriorating and pathogenic microbial. The parameters that can be evaluated and are related to the degree of contamination in milk are: protein, lactose, pH, fat content and conductivity [27].

The fat percentage, non fat solid content, protein content, lactose content, conductivity and pH in the analyzed samples were the parameters are in accordance with the legislation for 28 days when utilized *E. urograndis*, except electrical conductivity [6]. This parameter were above the levels established by the legislation, and this represented a possible contamination of the milk that facilitated conductivity. This is supported by the observed correlation obtained between the increase colony-forming units of PA of *E. urograndis* and this physical parameter [28] and the discussion need be investigated.

4. Conclusions

The vinegar wood of *E. urograndis* associated a glycerin is better than the use of vinegar wood associated with maltodextrin and does not present cytoxicity to mammary gland cells. Research should be conducted for better knowledge of the rational.

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Section 5

Nutrition

Chapter 11

Feeding Forage Cowpea: Goats Performed Well with High Nutrient Digestibility and Nitrogen Retention

Aminu Garba Bala and Mohammed Rabiu Hassan

Abstract

This chapter deals with the utilization and performance of Red Sokoto goats fed varieties of forage cowpea (*Vigna unguiculata*). It contains information for use right from keeping to precision production of goats. Background information is given on cowpea history and distribution, cowpea varieties and forage yields of cowpea (mainly in Africa and precisely Nigeria). Cowpea haulm nutritional value, mineral contents as well as anti-nutritional factors like tannins, saponins, oxalate, phytate and phenols are then detailed. The final sections highlight the performance of Red Sokoto goats in terms of nutrient digestibility and nitrogen retention when fed with two cowpea haulm varieties for optimum performance under smallholder production system.

Keywords: cowpea, digestibility, haulm, performance, varieties

1. Introduction

The role of livestock in providing protein is essential in human nutrition, and it is increasingly being recognized. This necessitates immediate concern in development programs for improvement of livestock productivity, through improved nutrition. Animal productivity could be increased by the introduction of low-cost technologies such as feeding systems that are simple, consistently practical and within the limits of the farmer's resources [1]. One of such feeding systems is the use of forage legume that supplies protein in fodder for livestock [2, 3]. Feeding of forage legumes has been found easily adoptable, but farmers do not pay particular attention to the planting of pure forage legume stands rather greater emphasis is on the cultivation of food crops. In Nigeria, the planting of cowpea is gaining popularity due to its huge economic returns on sales of grains and haulms, respectively. About 10.6 million ha of cowpea was estimated to be produced in West Africa, particularly in Niger and Nigeria [4].

Cowpea haulm is the above-ground part of cowpea without the pods which contains the grains [5]. The haulms contain about 45–65% stems and 35–50% leaves and sometimes roots [6], and are an important by-product in Sub-Saharan Africa [7].

Cowpea haulm addition improves nutrient supply and growth of livestock over the use of low-quality forages alone [8]. Previous studies by Osafo et al. [9] observed improved intake and digestibility of poor quality fodder with supplementation of cowpea haulm. The incorporation of promising legumes fodder such as cowpea haulms for livestock production will help to overcome the feed shortages. The Institute for Agricultural Research (IAR), Zaria-Nigeria, with other collaborating institutes has bred and released new cowpea varieties overtime with focus mostly on higher grain yield, while forage yield and quality is rarely a priority [10]. SAMPEA 14 and 15 varieties of cowpea are high yielding, striga-resistant and tolerant to heat and drought with maturity period of 70–78 days [11]. Considering the good qualities of this legume crop in the tropical savanna, the knowledge of its nutritive value will be very important. This chapter will provide information on the supplementation of two cowpea haulm varieties in concentrate diets for improved nutrient digestibility and nitrogen balance in Red Sokoto bucks.

2. Background information

Cowpea is gradually attaining economic importance in Nigeria, even though the bulk of the production is done in the semi-arid zone of Nigeria [12]. In Nigeria, the production trend of cowpea has experienced about 44.1% increase in area planted and 41% increase in yield from 1961 to 1995 [13]. The appreciating economic importance may be due to its food value and supplementary source of protein for animal use. Inaizume et al. [5] observed several factors that account for the impressive significant advances made by International Institution of Tropical Agriculture (IITA) over the last two decades in improving cowpea productivity in Sub-Saharan Africa. Singh et al. [14] also indicated that a number of varieties have been developed which combine diverse plant type, different maturity period and resistance to several disease, insect pest and parasite as well as good agronomic traits. The leaves, vines and some portions of the roots (haulms) serve are often stored for use during the dry season as animal feed. The sale of the haulms as animal feed during the dry season when there is a feed shortage and during festive season were livestock such as goats are slaughtered, thereby providing a vital income for farmers [15]. In this chapter, the background information is given on cowpea history and distribution, varieties and forage yields, nutritional value, anti-nutritional factors as well as nutrient digestibility and nitrogen retention when fed with two cowpea haulm varieties.

2.1 History and distribution of cowpea

Cowpea is one of the most ancient crops known to man. Cowpea (*Vigna unguiculata* L. Walp) is a member of the family *Fabaceae* and tribe *phaseoleae* [16]. Morphological features and geographical distribution are used in determining the origin of cowpea [17]. Early observations showed that the cowpeas present in Asia are very diverse and morphologically different from those growing in Africa, suggesting that both Asia and Africa could be independent centres of origin for the crop. Cowpea has been cultivated in southern Europe at least since the eighth century BC and prehistoric times [18]. However, Asia has been questioned as a centre of origin due to the lack of wild ancestors [19]. A lack of archaeological evidence has resulted in contradicting views supporting Africa, Asia and South America as its origin [20].

Carbon dating of cowpea (or wild cowpea remains) has been carried out by Flight [21]. The author reported that the oldest archaeological evidence of cowpea was found in Africa in the Kintampo rock shelter remains in Central Ghana dating about 1450–1000 BC, suggesting Africa as centre of origin. One view is that cowpea was introduced from Africa to the Indian subcontinent approximately 2000 to 3500 years ago [11]. Duke [22] based his conclusions on West Africa as the centre of cultivated cowpea. Kitch et al. [23] also reported that the species unguiculata is thought to be West African Neolithic domesticated.

Cowpea is now widely adapted and grown throughout the world, extensively in 16 African countries with the continent producing two-thirds of the world total [24]. The centre of maximum diversity of cultivated cowpea is found in West Africa, in an area encompassing the savannah region of Nigeria, southern Niger, part of Burkina Faso, northern Benin, Togo and the north western part of Cameroon [19]. *V. unguiculata* is known by different names throughout the world. In the United States, the crop is called black-eye peas or southern peas [19] and the English-speaking people in Africa refer to it as cowpea. In Nigeria, it is called “wake” [25]. Cowpea was now grown on an estimated 12.3 million ha in Africa in 2014 with the bulk of production occurring on 10.6 million ha in West Africa, particularly in Niger, Nigeria, Burkina Faso, Mali and Senegal [4].

2.2 Cowpea varieties in Nigeria

The International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria, is the centre for worldwide collection and testing of cowpea germplasm. The Institute for Agricultural Research-Zaria with other collaborating Institutes (i.e. IITA) has a cowpea breeding programmes that releases new varieties (such as SAMPEA 14 and 15) over a time with focus mostly on higher grain yields, while crop residue quality is rarely a priority [10, 26]. The Institute developed high yielding, short season and multiple disease-resistant varieties with varying maturity periods (that are ready for harvest in 60–70 days), as well as different seed colours, and adapted to various Nigerian agro-ecological zones. Several of these varieties have also been released in Nigeria and are being promoted by the State Agricultural Development Projects (ADPs), farmers’ groups and seed companies [10]. Considerations in variety selection should either be on growth pattern, maturity, market value, seed size and colour and resistance to the prevailing biotic and abiotic stresses in the areas to be planted. Generally, varieties differ in their adaptation to new ecology, in yield potential, maturity periods and canopy architecture [27]. Sampea 14 and 15 varieties of cowpea were chosen for the trial because of their relative promising performance in the Nigerian Savanna [11].

2.2.1 Sampea 14 and 15 varieties of cowpea

Sampea 14 is a semi-erect variety of seed that is characterized by small-sized and white colour seed. It has brown eye, rough seed coat and long peduncles that carries pod above canopy. The cowpea variety thieves well in Sudan and Sahelian agro-ecologies. It is an early maturing variety (70–75 days) with high seed yield (1.3 t/ha), producing 12–15 seed per pod. It is resistant to pod damage by striga/Alectra and also tolerant to heat and drought [11]. Sampea 15 is a creeping variety of seed that is characterized by small-sized and white colour seed. It has black eye, rough seed coat and long peduncles that carries pod above canopy. The cowpea variety thieves well in Sudan and Sahelian agro-ecologies. It is an early maturing variety (73–78 days) with high seed yield (1.3 t/ha), producing 12–15 seed per pod. It is resistant to pod damage by striga/Alectra and also tolerant to heat and drought [11].

2.3 Forage yields of cowpea

The annual production is high, but the average grain yield per hectare in Nigeria is only 776.31 kg/ha which though above the average yield worldwide of 521.91 Kg/ha in 2013, but is far lower than yield of 5333.33 kg/ha obtained in USA [28]. Yields of up to 8 t DM/ha have been recorded for cowpea in irrigated areas [29] and over 4 tDM/ha under favourable conditions [30]. The average fodder yield of cowpea in India is 25–45 t/ha [31]. However, the world average yield of cowpea fodder is 0.5 t/ha [32]. Farmers may harvest up to 0.4 t/ha of cowpea leaves in a few cuts with no noticeable reduction in seed yield. Cowpea crop can produce a yield of 1–2.5 t/ha fresh fodder and an intercrop cowpea can give 0.35–1 t/ha of fresh fodder. A dry forage yield of 0.23 t/ha and 2.86 t/ha forage yield from Sampea 14 variety of cowpea under rain-fed and irrigation condition, respectively, was also reported [33, 34]. In a study by Antwi et al. [35], a haulm yield of 13.35 t/has was recorded from improved dual purpose cowpea variety (IT93K-2045-93). Also, a dry cowpea fodder of 0.4–0.5 t/ha was produced at the end of the raining season under intercropping system in Sahelian and Sudan areas [36, 37]. Bundles of harvested fodder are stored on rooftops or on trees fork for use and for sale as "harawa" (feed supplement) in dry season. Singh et al. [38] reported that early and medium maturing varieties yielded higher grain but lower fodder than late maturing and fodder-type cowpea varieties which yielded 5 t/ha of fodder and less grain. However, the number of leaves and branches were positively correlated with green fodder yield [39]. Many reports have shown that higher number of leaves will allow animals to select forage with higher crude protein and digestibility [40] as leaves consist of two-third of forage feeding value [41].

2.4 Nutritional value of cowpea grains and haulms

Cowpeas are important legumes and sources of protein in livestock diets. Protein content of cowpea leaves varies within different genotypes [42]. Cowpea seed contains 25% crude protein [43, 44] with leaves containing 27–34% crude protein [45]. Protein content of cowpea leaves range from 27 to 43%, and protein concentration of the dry grain ranges from 21 to 33% [46]. The crude protein content ranges from 22 to 30% in the grain, from 6.9 to 7.1% in cowpea shell [47] and from 13 to 17% in the haulms [48] with a high digestibility and low fibre level [37]. An average crude protein of cowpea haulms (12.36%) was reported by [49] which was within the range of 8–13%, below which [50] observed that feed will not provide the required levels of ammonia for an optimum rumen microbial activities. Due to seasonal differences in the quality of haulms, care must be taken when handling to minimize loss of leaves [6]. The proximate composition of forage meal of cowpea at two stages of growth was found to be high in crude protein and either extract at flowering stage than at maturity [47].

The chemical composition of cowpeas has been shown to vary considerably according to cultivar and environmental [51] and genetic factors [52]. Dry matter digestibility of cowpea haulm is between 65 and 70% [53], and differs greatly between leaves (60–75%) and stems (50–60%). Because of this difference, the proportion of leaves and stems in the haulm affects its nutritional value [7]. Many reports have shown that higher number of leaves will allow animals to select forage with higher crude protein and digestibility [40] as leaves consist of two-third of forage feeding value [41]. As plants mature, even the leaves would become more fibrous and less digested [54]. A safe upper limit of 60% nitrogen detergent fibre (NDF) level for guaranteed forage intake by ruminant as it can be digested by ruminant animals [55]. It has also been reported that as the plant matured, photosynthetic products are more rapidly converted to structural components, thus having the effect of decreasing protein and soluble carbohydrate and increasing the structural cell wall components [56].

Sebetha et al. [57] studied the protein content of two cowpea varieties grown under different production practices in Limpopo province, Ghana. The results of the study revealed that cowpea leaf protein content ranged from 24.1 to 28.1% and 26.0 to 30.7% for *Red Caloona* and *Pan* 311, respectively. The protein content of green cowpea pods obtained from Pan 311 cowpea variety ranged from 18.8 to 25.1%, while that of *Red Caloona* varied between 17.9 and 20.7%. Similarly, the protein content of the fodder obtained after grain harvest varied between 9.3–9.4% and 9.9–12.3%, respectively, for *Pan* 311 and *Red Caloona* during the two seasons.

Anele et al. [58] observed that cowpea haulm can be used for sheep as a supplement to poor quality basal diets. Anele et al. [59] also observed that cowpea haulms can provide adequate protein and energy to sustain ruminant production during an extended dry season. Savadogo et al. [53] reported that the intake of cowpea haulms by sheep can reach 86 g/day as a supplement to sorghum stover. Although supplementation decreased total dry matter (DM) intake, this was compensated for by an increase in stover digestibility [53]. In sheep fed 200–400 g/day of cowpea haulms as a supplement to a basal diet of sorghum stover, the resulting average live-weight gain (80 g/day) was twice that obtained with sorghum fodder alone [60]. In male Ethiopian Highland sheep, supplementation of maize stover with cowpea haulms (150 or 300 gDM/day) improved dry matter and protein intake, organic matter (OM) digestibility, average daily gain, final live weight, carcass cold weight and dressing percentage [61].

2.4.1 Mineral contents of cowpea haulms

Mineral contents of forage species are influenced by genetic factors [52] and climatic and soil factors on which plant grows [51]. Variations in the concentrations of minerals are due to the differences in nutrient uptake from the soil [62]. Alhassan et al. [47] also revealed that the proximate and mineral composition of forage meal of cowpea at two stages of growth to higher in minerals which is fairly high in calcium (Ca), sodium (Na) and potassium (K) at flowering stage than at maturity but low in phosphorus. Deficiency of phosphorus (P) in legumes depressed the activity of nitrogen-fixing bacteria [63] for which the availability of nitrogen in root zone is also reduced. P concentration in herbage decreases with increase in maturity [64]. In a trial by Abia [64], a mean range of calcium content of 1.6–2.0% was reported for tropical legumes with a range of 0.5–1.1 g/day will be able to satisfactorily meet the daily Ca requirement of goats [65]. NRC [66] recommended 0.15 and 0.80% for of P and K, respectively, while a range of 0.71–0.21 g/100 g magnesium (Mg) was recommended for small ruminants [67].

2.4.2 Anti-nutritional factors of cowpea haulms

Anti-nutritional factors are a chemical compounds synthesized in natural food and/or feedstuffs by the normal metabolism of species. They are also known as toxic factors due to their deleterious effect when consumed by animals. Toxicity due to the consumption of various forages is very common among the farm animals. The anti-nutritional factors present in the forages are mainly responsible for this [68]. The presence of anti-nutritional substances in any of the edible legumes is of major concern. Cowpea (*V. unguiculata* L. Walp) has been utilized as a supplement feed to enhance feed intake and improve productivity in ruminants fed low-quality roughage diets [69]. Cowpea forage contains anti-nutritive factors, which includes, but not limited to tannins, oxalate, saponins, phytate and phenol [70]. These anti-nutritional factors are also known as "secondary metabolites" in plants and they have been shown to be highly biologically active [71].

2.4.2.1 Tannins

Cowpea forage contains tannin [70], which is a bitter plant and water-soluble phenolic compounds with the ability to precipitate protein from aqueous solution [72]. Tannins are the most widely occurring anti-nutritional factors found in plants. Tannins in feed stuffs such as pasture legumes decrease palatability and protein digestibility [73]. Hydrolysable tannins and condensed tannins are two different groups of tannins [68], differing in their nutritional and toxic effects. Smitha et al. [68] reported that tannins in forage legumes have both positive and negative effect on nutritive value. Condensed tannins containing forages have different benefits for ruminants, depending on the species of plant [74]. The condensed tannins have more profound digestibility-reducing effect than hydrolysable tannins, whereas the latter may cause varied toxic manifestations due to hydrolysis in rumen [75]. Tannins forms insoluble complexes with proteins, and the tannin protein complexes may be responsible for the anti-nutritional effects of tannin containing feeds [71]. The tannin-protein complexes are astringent and adversely affect feed intake.

The concentration of condensed tannins above 4% (40–100 g/Kg DM) has been reported to be toxic for ruminants as they are more resistant to microbial attack and are harmful to a variety of microorganisms [76] and depressed feed intake and growth in ruminants [77]. Goats are known to have a threshold capacity of 9% (90 g/kg/DM) dietary tannin [78]. Ravhuhali et al. [79] reported that some cowpea forage cultivars had high amounts of condensed tannins (0.11%, DM basis), but these did not exert negative effects on intake and digestibility. A study by Adjei-Fremah et al. [80] on analysis of phenolic content and antioxidant properties of selected cowpea varieties tested in bovine peripheral blood revealed that there was variation among leaf samples from the different cowpea varieties for condensed tannins. Low levels of condensed tannins were observed in all fresh leaves samples ranging from 0.13 to 0.22 mg/100 g compared to high condensed tannins content in dry leaves samples (0.30–0.52 mg/100 g). This may be an important consideration in the use of cowpea for animal feed either as hay or silage. However, the range of values for all the content of tannins in all varieties was below 5% DM, the critical value above which tannins interfered with intake, digestion and utilization of forages [81].

2.4.2.2 Saponins

Saponins are secondary compounds that are generally known as non-volatile, surface active which are widely distributed in nature, occurring primarily in the plant kingdom. The structural complexity of saponins results in a number of physical, chemical and biological properties, which include sweetness and bitterness, foaming

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and emulsifying, pharmacological and medicinal as well as antimicrobial, insecticidal activities [71]. Saponin content of the leaves is twice as much as those of the stems and declines as the plant becomes older. The tolerable level of saponin in goat is 1.5–2% [82]. Saponins are among several plant compounds which have beneficial effects. Among the various biological effects of saponins are antibacterial and antiprotozoal [83].

2.4.2.3 Oxalate

Oxalate binds with nutrients to render their availability to the animal body, thus resulting in nutritional deficiencies. Oxalate also reacts with proteins to form complexes which have an inhibitory effect in peptic digestion [84]. In ruminants, oxalic acid is of only minor significance as an anti-nutritive factor since ruminal microflora can readily metabolize soluble oxalates to its calcium salts [71, 85]. Various tropical grasses contain soluble oxalates in sufficient concentration to induce calcium deficiency in grazing animals. Oxalates react with calcium to produce insoluble calcium oxalate, reducing calcium absorption. Calcium oxalate adversely affects the absorption and utilization of calcium in the animal body [75]. Ruminants, unlike monogastric animals, can consume considerable amounts of high oxalate plants without adverse effects, principally due to microbial degradation in the rumen [71]. Plants containing about 10% oxalate on dry weight bases cause toxicity [73]. During early stages of growth, there is a rapid rise in oxalate content with concentrations as high as 6% followed by a decline in oxalate levels as the plant matures [73].

2.4.2.4 Phytate

Phytate, which is also known as inositol hexakisphosphate, is a phosphorus containing compound that binds with minerals and inhibits mineral absorption. The cause of mineral deficiency is commonly due to its low bioavailability in the diet. Phytates are generally found in feed high in fibre especially in legumes such as cowpea haulms and have been associated with reduced mineral absorption due to the structure of phytate which has high density of negatively charged phosphate groups which form very stable complexes with mineral ions causing non-availability for intestinal absorption [86].

2.4.2.5 Phenols

Cowpea contains significant amounts of phenolic compounds including phenol acids [87]. Cowpea phenol compounds have health benefits for animals due to their antioxidant [88]. The antioxidant capacity of phenols in different cowpea varieties has been reported. Phenols and their antioxidant activity function to protect cells from oxidative stress which has been implicated in the cowpea leaves and husk that have high nutritive values [89, 90]. Cowpea leafs extract showed antioxidant properties in cow blood; thus, this suggests a possible role in regulating oxidative stress in cow blood [80]. Oxidative stress plays a key role in several pathological conditions connected with animal production and reproduction [91]. Oxidative stress affects the health status of animals as well as product quality such as milk and meat [92]. Lowered antioxidant status is predominant in ruminants during mastitis, retained placenta, acidosis, ketosis and milk fever conditions [93]. The use of cowpea forage as supplement feed impacts milk and meat antioxidant capacity and the overall quality of products. Phenols also exhibit antimicrobial effect against pathogenic bacteria [94].

Mokoboki et al. [81] study sixteen cowpea forage varieties grown under similar soil and management conditions at the University of the North Experimental Farm. After harvesting, the cowpea forages were dried and then analysed for content of dry matter, crude protein, total phenols, condensed tannins, packed volume and water retention. Results revealed that cowpea varieties (TUV11424 and IT85D385) had a total phenols range of 0.75–1.96% DM which suggest no or minimal detrimental effects on protein levels adequate to promote fibre digestion in the rumen. This could reduce live weight losses in ruminant animals in rural areas during the dry season when crop residues are the main feed resource.

3. Methodology

The feeding trial and nutrient digestibility study was conducted at the Sheep and Goat Unit of College of Agriculture and Animal Science, Division of Agricultural colleges, Ahmadu Bello University, Mando-Road, Kaduna State. The farm is located at an elevation of 676 m and latitude of 10°35'N and longitude of 7°25′ E [95]. Fifteen experimental Red Sokoto bucks of an average weight of 10 kg were used for the experiment. The animals were balanced for initial weights before they were allocated to three treatment diets with five bucks per treatment in a complete randomized design. The animals were allowed 14 days to adjust to feed and confinement before the actual start of the experiment that lasted for a period of ninety days.

The three treatment diets consisted of *Brachiaria decumbens* hay as basal diet. Concentrate diets (14% CP) was supplemented with cowpea haulms at 0% (Control), 10% (SAMPEA 14) and 10% (SAMPEA 15). The basal forage diet was fed *ad libitum* after feeding the supplements in order to ensure maximum supplement consumption at the rate of 1% of body weight per head per day in the morning (08:00 am). Water and mineral salt lick were provided *ad libitum* for the period of 90 days. All bucks were weighed at the beginning of the experiment and fortnightly thereafter to determine the live-weight changes and to adjust the amount of feed offered in order to maintain the pre-determined level of 3% feeding of the animal's body weight for the periods in confinement.

At the end of the feeding trial, three animals were randomly selected from each of the three treatment groups and housed in metabolic creates for total faecal and urine collection as described [96]. The bucks were maintained on the same treatment diets used in the feeding trial and were allowed 14 days adjustment period before the start of the digestibility studies. Each morning (8.000 am), feed left over, faecal output and urine output were collected and weighed for 7 days. The daily total faecal output collected form each buck was weighed and bulked, and subsample was taken for analysis. The daily urine output from each buck was collected into a plastic container containing 10 ml of 0.1 M H_2SO_4 placed under the metabolic creates to prevent nitrogen loss by volatilization. Urine collected was bulked, and about 10% of the total urine output was subsampled for each buck and stored in the refrigerator pending nitrogen determination. Feed samples offered, feed left over and faecal output were analysed for chemical compositions, and urine samples have been analysed for nitrogen using the method described by SAS [97] at the central laboratory of National Animal Production Research Institute, Shika-Nigeria. Data collected on were analysed using Analysis of Variance (ANOVA) by General Linear Model procedures [98]. Data on rumen metabolites and fortnightly weight changes were analysed using repeated measures ANOVA and trend analysis. Treatment means were separated using Dunnett's test.

4. Nutrient digestibility and nitrogen retention: concentrate diets supplemented with two cowpea haulms varieties and *B. decumbens* hay basal

An on-farm experiment was conducted in Samaru-Zaria, North-Western Nigeria, by Bala et al. [99] to evaluate the effect of supplementating two cowpea haulm varieties in concentrate diets for Red Sokoto bucks as presented in **Table 1**. Results revealed that digestibility of dry matter, crude protein, crude fibre, ether extract and nitrogen-free extract were found to increase with inclusion of cowpea forage. The most probable explanation for this phenomenon is in the fact that diet at 10% inclusion level of Sampea 14 cowpea forage might result in high palatability, increased activity of rumen microorganisms for rapid fibre digestion in the rumen and better utilization of the nutrients by bucks. The improvement in digestibilities of nutrients in response to legume supplementation is in line with the reports of

Parameter	Control (0%)	Sampea 14 (10%)	Sampea 15 (10%)
Cowpea haulm	0.00	10.00	10.00
Maize offal	35.46	27.33	31.08
Rice offal	30.00	30.00	30.00
Cottonseed cake	32.54	30.67	26.92
Bone meal	1.50	1.50	1.50
Common salt	0.50	0.50	0.50
Total	100.00	100.00	100.00
Calculated analysis:			
Crude protein(%)	14.46	14.19	14.41
M.E (Kcal/kg)	3090	3059	3051

ME = Metabolizable energy.

Table 1.
Ingredient composition of concentrates containing cowpea haulms supplements.

Parameters (%)	Sampea 14 haulm	Sampea 15 haulm	*Brachiaria. decumbens* hay
Dry matter	89.66	88.52	87.39
Crude protein	16.11	15.55	7.31
Crude fibre	27.88	28.50	28.8
Ether extract	1.83	1.55	0.93
Nitrogen-free extract	47.34	51.48	42.18
Ash	5.28	5.88	5.14
Neutral detergent fibre	59.97	61.4	62.06
Acid detergent fibre	34.03	35.3	30.76
Lignin	17.18	18.4	7.21

Table 2.
Chemical composition of the two varieties of cowpea haulm and Brachiaria decumbens hay.

	Control	Sampea 14	Sampea 15 (%)	
Nutrient digestibility (%)	**0**	**10**	**10**	**SEM**
Dry matter	51.10^{b}	75.81^{a}	54.11^{b}	1.87
Crude protein	61.19^{b}	77.41^{a}	61.71^{b}	2.30
Crude fibre	63.22^{c}	86.08^{a}	72.87^{b}	1.31
Ether extract	26.62^{b}	39.17^{a}	27.57^{b}	2.49
Ash	41.72^{a}	32.83^{b}	24.94^{c}	3.03
Nitrogen-free extract	60.06^{b}	84.41^{a}	67.34^{b}	1.98

[abc] Means with different superscripts along the row differed significantly (P < 0.05).
SEM = Standard error of means.

Table 3.
The effect of feeding two cowpea haulm varieties on nutrient digestibility in Red Sokoto bucks fed Brachiaria decumbens hay as basal diet.

Nitrogen balance (g/day)	**Control**	**Sampea 14**	**Sampea 15 (%)**	
	0	**10**	**10**	**SEM**
Nitrogen intake	5.07	6.43	5.46	0.68
Faecal Nitrogen	3.45	2.13	3.46	0.72
Urinary Nitrogen	0.94	0.51	0.81	0.45
Total nitrogen loss	4.39^{a}	2.64^{b}	4.28^{a}	0.77
Nitrogen retained	0.67^{b}	3.79^{a}	1.18^{b}	0.62
Nitrogen absorbed	1.61	2.80	1.68	1.11

[abc] Means with different superscripts along the row differed significantly (P < 0.05).
SEM = Standard Error of Mean.

Table 4.
The effect of feeding two cowpea haulm varieties on nitrogen balance in Red Sokoto bucks fed Brachiaria decumbens hay as basal diet.

Nsahlai and Umunna [100]. Also, it may be attributed to the quality of Sampea 14 cowpea forage, which might have improved the digestibility of other poor-quality roughages. The improvement in CP digestibility due to cowpea hay supplementation could be attributed to the high CP content of the legumes as argued by Murphy and Colucci [101].

Nitrogen retention (N) is the major indicator for accessing the protein nutritional status of ruminant livestock [102]. The N retained recorded in bucks fed 10% Sampea 14 forage inclusion levels as shown in **Table 2** is in agreement with the report of Yashim et al. [103] that N depends on good digestibility of nutrients and or utilization. The low N retention for bucks given the control diet could be due to the inadequacy of the diet to maintain N equilibrium and, consequently, live-weight [104]. In the study, the significantly higher N retained and lower N loss in bucks fed 10% Sampea 14 forage inclusion levels cowpea forage indicated that it contained enough digestible nutrients to provide nutrient retention for better performance in Red Sokoto bucks. However, the better N retention in the diet supplemented with Sampea 14 cowpea haulm could be due to a higher rumen degradable protein available which reduced then total N losses. Elseed et al. [105], however, observed that supplementation of protein sources improved microbial N yield and N retention (**Tables 3** and **4**).

5. Conclusions

Farmers could incorporate cowpea forage/haulms in concentrate diet of Red Sokoto bucks for optimum performance under smallholder production system.

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Section 6

Adaptation to Global Warming

Chapter 12

Adaptation of Desert Goats to Solar Heat Load and Water Restriction as Indicators of Climate Change under Semi – Arid Condition

Hind Abdelrahman Salih, Ibrahim Bushara and Siham A. Rahmatalla

Abstract

This experiment was conducted at Elobeid ARC Farm, North Kordofan State, Sudan, and covered hot summer, rainy, winter, and warm summer seasons for 310 days. Thirty-six non-pregnant Desert goats were used in this experiment. One group was randomly allocated to a shaded condition and the other to an unshaded condition. Each group was randomly subdivided into two groups, one group receiving water every day and the other receiving water every other day. Does were mated by using two healthy Desert bucks. For both shaded and unshaded conditions, respiration rate (RR) and rectal temperature (RT) were significantly ($P < 0.001$) higher in unshaded than shaded conditions. The watering regime seemed to have no effect. Conception and kidding rates were lowest with the every other day watering regime under both shaded and unshaded conditions, while abortion rates were highest with the every other day watering regime under unshaded conditions. Does the mortality rate was highest in the shaded condition with the everyday watering regime and under the unshaded condition with the every other day watering regime? Kids' mortality rate was 100% under the unshaded conditions with the every other day watering regime. Kids' birth weights were higher under shaded conditions with every day watering regime or under unshaded conditions with every other day watering regime.

Keywords: desert goats, shade, watering regime, physiological responses, performance

1. Introduction

Goats are good substitutes for traditional animal production in hot climatic conditions owing to their ability to adapt to different environments [1, 2]. The animals possess both phenotypic adaptive features and the genetic mechanism that guarantee thermo tolerance in harsh environments around the world. With combinations of diverse morphological, behavioral, physiological, and genetic traits, goats

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could adapt to heat stress [3]. Goats are also an essential source of animal protein and family cash income for small-scale farmers in assorted countries around the world [4]. Importance of animal production in Sudan is attributable to high population, large allocation, adaptation to a huge range of environments, and socioeconomic impacts [5]. According to the Sudan Ministry of Animal Resources' most recent estimate (2021), the main livestock population is over 110 million heads, with 32.081 million cattle, 41.127 million sheep, 32.402 million goats, and 4.944 million camels. Most of this wealth is owned by nomads [6].

Goat production is imperative in Sudan because goats have been raised successfully with very restricted feed resources [7]. Goats' population is highest in North Kordofan State, followed by South Kordofan State; they are a favorite domestic dual-purpose animal in Sudan, due to their role in the country's economy and in the lives of many Sudanese communities (milk and meat) [8].

Desert goats are chiefly raised for meat production, especially in rural areas, in Sudan, and other dry environment [9]. Also, they are resources for milk and fiber [10]. They are Savanna type, identical to West African Long-Legged, disseminated in arid areas generally to the north of 10°N in North Kordofan State within arid and semiarid agro-ecological zones and represent about 17% of the goat population in Sudan. It is raised under pastoral and agro-pastoral systems [11]. Although, the wide variety of quantitative traits observed and also they are good animals for adaptation in harsh environments and have a positive impact on performance [12].

Livestock genetic enhancement should take into account not only production characteristics (milk yield, weight gain, and wool production), but also the interaction of those characteristics with environmental factors (i.e. air temperature, relative humidity, and solar radiation) [13], so the reaction of native goats to climatic and environmental factors must be accurately understood before attempts are made to increase their productivity levels. This study was conducted for delineating some environmental factors that cause variability in some physiological responses and reproduction of Sudan Desert goats.

2. Literature review

2.1 Some physiological responses to environmental stress

Climate change plays an essential role that threatens the survival of livestock, where variables in temperature, humidity, and radiation are the most serious factors that affect the growth and production ability of livestock [14]. Animals have diverse adaptive mechanisms to cope with the climate change [15]. The adaptive ability of the animals is determined by the morphological, anatomical, physiological, biochemical, and behavioral characteristics of these animals which help them to survive in a particular environment [16]. Physiological adjustments are fundamental to maintain normal body temperature and prevent hyperthermia [17]. Physiological responses like respiration rate, heart rate, and rectal temperature give an immediate response to heat stress and therefore the level of animal discomfort/comfort [18, 19].

Changes in respiration rate, heart rate, and rectal temperature have been usually used as indices of physiological adaptability to heat stress in small ruminants [20–23]. Increased body temperature and respiration rate are the most principal signs of heat stress in sheep and goats [24, 25].

Respiration rate is an actual and credible measure of heat load and a sign of heat stress [25, 26]. Without confusing the animals, from 4 to 5 meters away [27], or from a non-disruptive distance [21] respiration rate is recorded by counting flank movements/minute. In normal conditions, the respiration rate of goats ranges between 15 and 30 breaths/min [28].

Therefore, measuring respiration rate and determining animal heat stress severity according to panting rate (breaths/min) (low: 40–60, medium: 60–80, high: 80–120, and severe heat stress: >200) appears to be the most attainable method for evaluating the impact heat stress on animals under extreme environment [1, 29].

Respiration rate may access 300 breaths/min with open-mouthed panting is a signal of severe heat stress [1]. Increased respiration rate following heat stress has been noticed in goats [30].

Rectal temperature is conceded as the most suitable indicator for heat load in animal's body as well as it is considered as a main measure of physiological status [31] and animal's core body temperature [32]. When an animal exposure to a high quantity of heat stress, the failure to dissipate heat load to maintain body temperature leads to increases in RT [32]. The RT was recorded using a clinical thermometer by inserting the thermometer by 6–7 cm inside the rectum inclined toward the wall of the rectum.

Body temperature is stable in the normal situation and it is one of the indicators of heat stress [29]. Rising in rectal temperature of 1°C or less reduce the majority of livestock species' performance [33]. Physiological responses to heat stress lead to protect animals from heat stroke but also decrease productivity [34].

Goats' normal rectal temperatures are between 39.2°C and 39.8°C [35]. Although rectal temperature increased from 37–41°C due to heat exposure [35, 36], but no changes were reported in goats exposed to different heat treatments [25, 37].

However, it is necessary to mention that intricacy and physiological changes due to heat stress response can differ from species to species, individual to individual, and the hormonal status of the animal [13].

2.2 Water scarcity and heat stress effect on goats' reproductive performance

Small ruminants are an integral part of farming systems in harsh environments areas where the rainfall, is becoming even more irregular and water availability more limited as a consequence of climate change [38]. Water deprivation and water restriction effects on small ruminants in arid and water-limited areas with a view of assessing their adaptive responses or changes in performance are gaining global attention [39]. In semi-arid regions during the dry season period, water intake by an animal is usually restricted to once per day [40]. Small ruminants have gained attention from scientists and communal farmers due to their ability to tolerate different watering regimes during periods of water scarcity without dangerous effects on production indices. However, there exist differences in the level of adaptation to intermittent watering across different breeds. Researches investigating the potential of the adaptable breed to low water intake are still limited, more studies are needed to fully explore water tolerance capacity in adaptable breeds in the form of water restriction or deprivation and across all physiological stages [39].

The effect of heat stress differs among regions, animal species, and the type of production which could either be positive or negative [41]. Reproduction parameters were very receptive to heat stress but, the stress levels depend on breed types. Exposure of goats to heat stress results not only in changes in physiological functions but also, in an impact on the production and productivity of the animals [42–44].

Severe surrounding temperatures are the major restraint to animal productivity. Heat stress during summer is a major contributing factor to the low fertility of domestic animals inseminated in the summer months [45]. The effects of heat stress on fertility are more distinct in lactating animals because the huge amounts of heat produced as a result of lactation make it difficult to regulate body temperature during heat stress [46]. In general, heat stress circumstances significantly affect the sexual behavior, decrease the sexual activity, and thus reduce sperm quality resulting in poor conception [47].

Goats and sheep have the ability to adapt to harsh environments, depend on their physiological mechanisms to be tolerant of these conditions, and are able to survive and resist diseases with good reproduction rates. The success of its rearing in arid and semi-arid regions indicates the possibility of being an alternative producer to counter the potential effects of climate change [48].

2.3 Stress - Body weights interactions

As a result of high temperatures, different species reduce feed intake, which leads to a decrease in growth rates thus a loss in body weights [49, 50]. When the ambient temperature increases animals need to dissipate metabolic heat, therefore feed intake decreases as a response to facing heat stress situations [51]. Many studies have been conducted on different species of goats that have proven the negative impact of high temperature and water deprivation on growth rates and body weights [52–56]. Increasing temperature from 25 to 45°C with humidity at 35–45% significantly causes a reduction in feed intake with increasing in water intake [57].

3. Materials and methods

3.1 Study area

This experiment was conducted at El-Obeid Agricultural Research Station Farm, in Sheikan Province, North Kordofan (Latitudes 11^{o}: 15′ to 16^{o}: 30' N and longitudes 27 to 32^{o} E), Sudan. The period of the experiment covered hot summer, rainy, winter, and warm summer seasons, with an average temperature of 32.1°C and an average relative humidity of 48.0%, 26.8°C and 66.0%, 22.7°C and 29.7%, and 25.3°C and 17.7% respectively.

3.2 Experimental animals

A total of 36 non-pregnant Desert goats were used in this experiment. They were brought from Bara Province, 65 km north-east of El-Obeid City. The does were 1–4 years old and weighing 17.7 ± 0.4 kg. Upon arrival the does were ear-tagged, drenched with an antihelmintic against internal parasites, injected with oxytetracycline as an anti-coccidial treatment, and allowed one week adaptation period. Does were then divided into two equal groups in such a way that the different ages and weights were evenly distributed throughout each group. One group was randomly allocated to a shaded condition and the other to an unshaded condition. Shaded pens of 2x3 m^2 each was used to accommodate three animals tethered to individual pegs and provided with individual feeding and water troughs. The animals kept under unshaded conditions were treated similarly. Each group was further randomly subdivided into two groups, one group receiving water every day and the other receiving water every other day. When using either regime, the animals were allowed water once a day for 1 hour. All animals were given food *ad libitum*, which consisted of straw (30%), groundnut seed cake (25.4%), wheat bran (42.4%), bone meal (2.0%), and common salt (0.2%) (**Figures** 1 and **2**).

3.3 Data records

3.3.1 Respiration rate (RR) and rectal temperature (RT)

All animals were weekly monitored for respiration rate (RR) and rectal temperature (RT), were measured twice on the measurement day, in the morning at 08:00 and afternoon at 13:00. RR was measured by counting the flank movements for 1 minute, while RT was determined by using a clinical digital thermometer inserted in the rectum for 1 minute.

3.3.2 Reproductive measurements

Throughout all the experiment period which covered hot summer, rainy, winter, and warm summer seasons, does were naturally mated when observed in heat by using two healthy Desert bucks. Conception, abortion, kidding, and mortality in both does and kids rates were recorded.

3.3.3 Body weights

The body weight of each animal was recorded at the beginning of the experiment, then every two weeks until the end of the experimental period. The does were weighted in the morning following an overnight fast. In addition, kids' weights were also recorded once at birth.

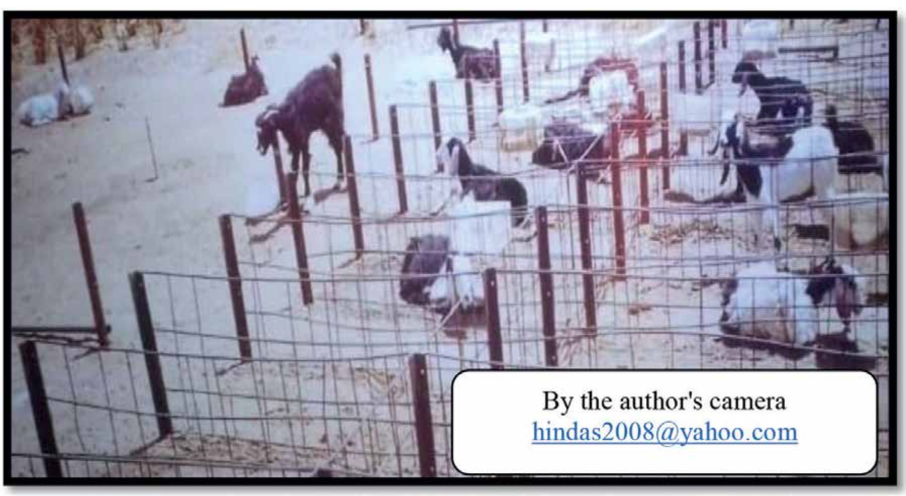

Figure 1.
Desert goats under unshaded condition. Source: Study results.

Figure 2.
Desert goat orientation to seek shelter under feed trough. Source: Study results.

3.4 Statistical procedures

The data was analyzed as a completely randomized block design using a 2x2 factorial arrangement to study the effect of shade conditions and watering regime on does' performance. Significant differences between means were separated using Duncan's Multiple Range Test.

The statistical analyses were done using MSTAT-C and SAS software programs.

4. Results

4.1 Effect of seasons, shade conditions, and watering regime on respiration rate (RR) and recta temperature (RT)

For comparison between seasons, as well as effects of shade conditions and watering regime throughout the experimental period (310 days) showed that goats during hot summer and rainy seasons had significantly ($P < 0.001$) higher RR than winter or warm summer. RT showed a similar trend except that rainy and warm summer did not show significant differences.

For both shaded and unshaded conditions, RR and RT were significantly ($P < 0.001$) higher in unshaded than shaded environments. The watering regime seemed to have no effect (**Table 1**).

4.2 Effect of shade conditions and watering regime on reproductive performance

The number of goats that become pregnant in each treatment were 4, 3, 4, and 2 goats, respectively. Conception and kidding rates were lowest with every other day watering regime under both shaded and unshaded conditions, while abortion rates were highest with the every other day watering regime under unshaded conditions.

Does mortality rate was highest in the shaded condition with the everyday watering regime and under unshaded conditions with the every other day watering regime.

Factor	RR (r/min)	RT (°C)
Seasons:		
Hot summer	47.3[a]	38.2[a]
Rainy	49.1[a]	37.9[ab]
Winter	33.4[b]	36.9[c]
Warm summer	34.4[b]	37.5[bc]
Mean	41.1	37.7
±SE	0.80	0.33
Shade conditions (310 days):		
Shaded	30.3[b]	37.0[b]
Unshaded	51.8[a]	38.3[a]
Mean	41.1	37.7
±SE	0.57	0.24
Watering regime (310 days):		
Every day	40.5	37.5
Every other day	41.6	37.9
Mean	41.1	37.7
±SE	0.57	0.24

[a,b,c] Means in columns with different superscripts are different at ($P < 0.05$) according to Duncan's Multiple Range Test.
Source: Study results.

Table 1.
Effect of season, shade conditions and watering regime on respiration rate (RR) and rectal temperature (RT) of dry desert goats.

Kids' mortality rate was 100% under the unshaded environment with the every other day watering regime. Kids' birth weights were higher under shaded conditions with every day watering regime or under unshaded conditions with every other day watering regime (**Table 2**).

4.3 Effect of shade conditions and watering regime on dry desert goats' final weights

For both shaded and unshaded conditions, the final body weights of dry Desert goats were significantly ($P < 0.05$) higher in shaded than unshaded environments. The watering regime showed no significant effect (**Table 3**).

5. Discussion

5.1 Effect of seasons, shade conditions, and watering regime on respiration rate (RR) and recta temperature (RT)

Physiological responses like respiration rate, heart rate, and rectal temperature give an immediate response to heat stress and therefore the level of animal discomfort/comfort [18, 19]. The period of the experiment covered hot summer, rainy,

Parameters	Shaded		Unshaded	
	Watering regime		Watering regime	
	Every day	Every other day	Every day	Every other day
No. of goats	9	9	9	9
No. of goats conceived	4	3	4	2
Conception rate %	44.4	33.3	44.4	22.2
Abortion rate %	0.0	0.0	0.0	50.0
Kidding rate %	44.4	33.3	44.4	11.1
Does mortality rate %	22.2	11.1	0.0	22.2
Kid mortality rate %	25.0	0.0	25.0	100
Av. Kid birth weight (kg) ± SD	2.1 ± 0.92	1.9 ± 0.14	1.8 ± 41	2.0 ± 0

Source: Study results.

Table 2.
Effect of shade conditions and watering regime on goats' reproductive performance.

Factor	Initial body Weight (Kg)	Final body Weight (Kg)
Shade conditions (310 days):		
Shaded	18.7	19.3^{a}
Unshaded	17.7	18.1^{b}
Mean	18.2	18.7
±SE	0.32	0.33
Watering regime (310 days):		
Every day	18.0	18.4
Every other day	18.4	19.0
Mean	18.2	18.7
±SE	0.32	0.33

[a,b] Means in columns with different superscripts are different at (P < 0.05) according to Duncan's Multiple Range Test.
Source: Study results.

Table 3.
Effect of shade conditions and watering regime on body weights of dry desert goats.

winter, and warm summer seasons, with an average temperature of 32.1 °C and an average relative humidity of 48.0%, 26.8°C and 66.0%, 22.7°C and 29.7%, and 25.3°C and 17.7%, respectively. Accordingly, throughout the experimental period (**Table 1**) showed that goats during hot summer and rainy seasons had significantly higher RR than winter or warm summer. RT showed a similar trend except that rainy and warm summer did not show significant differences. These results are in agreement with the findings of Silanikove [1, 29] were indicated that, measuring respiration rate and determining an animal's heat stress severity according to panting rate (breaths/min) (low: 40–60, medium: 60–80, high: 80–120, and severe heat stress: >200) appears to be the most attainable method for evaluating the impact of heat stress on animals under the extreme environment where the results indicated that the experimental animals in a level of low heat stress (40–60 breaths/min) during both hot summer and rainy seasons.

In the present results, it could be seen that the net impact of thermal radiation was more pronounced on goats' performance than water restriction, this is substantiated by Doreau et al. [40] who indicated that small ruminants have gained attention from scientists and communal farmers due to their ability to tolerate different watering regime during periods of water scarcity without dangerous effects on production indices. However, there exist differences in the level of adaptation to intermittent watering across different breeds. Researches investigating the potential of the adaptable breed to low water intake are still limited, more studies are needed to fully explore water tolerance capacity in adaptable breeds in the form of water restriction or deprivation and across all physiological stages.

Body temperature was maintained in spite of fluctuations in environmental temperature. However, this species was unable to increase their diurnal body temperature by more than 1–2°C in response to heat stress. Panting was used preferentially to sweat to maintain body temperature. Yet heat tolerance depended on water availability to support evaporative loss. During the rainy season, high humidity seemed to have depressed evaporative heat loss and added to the heat load. This was reflected by the high body temperature observed in animals exposed to the unshaded condition under both watering regimes.

5.2 Water scarcity and heat stress effect on goats' reproductive performance

Water deprivation and water restriction effects on small ruminants in arid and water-limited areas with a view of assessing their adaptive responses or changes on performance are gaining global attention [40]. In the present study (**Table 2**), the combination of exposure to solar heat load and water restriction reduced conception rates, which was more pronounced in animals exposed to heat stress with water restriction. Similarly, it has been shown that an increase of 1°C in ambient temperature caused a decrease of 2% in conception rate [58], this is in agreement with the findings by [43–45] reported that reproduction parameters were very receptive to heat stress but, the stress levels depend on breed types. Exposure of goats to heat stress results not only in changes in physiological functions but also, in an impact on the production and productivity of the animals.

Generally, the kidding rate was low under all treatments, it decreased with water restriction but was very much reduced with exposure to heat load. Does and kid mortality rates bear no relation to each other. Does mortality rate was high under shaded conditions with water offered every day and was the same to those exposed to heat load while being watered every other day. The mortality rate was nil for does watered every day under unshaded conditions. The kids mortality rate was 100% under heat stress conditions, but nil under shaded conditions when does watered every other day. Kids were more susceptible to heat stress conditions. Birth weights in the present results were within the normal range reported by [59, 60]. In the present study, kids were born in different seasons and their mortality could be related to the season of birth.

5.3 Effect of shade conditions and watering regime on dry desert goats' final weights

Numerous studies have been conducted on the effect of climatic factors on feed intake by controlling the factors in laboratories, but it is difficult to apply the same accuracy in the field because of the large differences between climatic factors in the natural field [51].

In the present study (**Table 3**), the changes in body weight due to the watering regime were not significant. However, goats exposed to solar heat load showed significant losses in body weight, similarly with many studies have been conducted on different species of goats that have proven the negative impact of high temperature and water deprivation on growth rates and body weights [52–56]. The same observation was reported by Helal et al. [61], who found that exposure of goats to solar radiation increased the loss in the live body weight of the goats.

6. Conclusions

It could be concluded that exposure of animals to direct solar heat radiation had a more adverse effect than water restriction. The condition was further exacerbated in the hot humid environment experienced by animals during the rainy season. Although the conception rates were low, but the low does' mortality rates indicated that Sudan Desert goats are well adapted to the harsh environment and climate change.

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Conflict of interest

No conflict of Interest.

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Section 7

Socio-Economics – Adaption Knowledge for Survival

Chapter 13

Socio-Economic Characteristics, Adoption, and Knowledge Level of Goat Farmers: A Study in Aspirational Districts of West Bengal, India

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Abstract

A study on socio-economic condition and challenges encountered by the farmers was done in purposively selected five districts of West Bengal, India. About 5000 respondents were randomly chosen for this study. The study of various socioeconomic indicators suggests that most goat farmers in these districts were illiterate and belong to the lower economic status. It had been noted that women were primarily involved in raising goats, and their financial situation was precarious. Most of these farmers had educational levels below the 10th standard and were engaged in domestic labor. The majority of these farmers had not had any training in scientific animal husbandry techniques; therefore, offering appropriate training in this area could be beneficial for their ability to support themselves. Given that these farmers have limited land holding capacity, goat farming could be a potential alternative to improve their financial situation. As a whole promotion of goat husbandry could be an ideal intervention to improve the socioeconomic condition of these farmers whose livelihood was in stake. It has been observed that various obstacles, such as a lack of training initiatives and educational opportunities, were the main hindrances for improving the socioeconomic well-being of farmers in the selected districts of West Bengal.

Keywords: goat farmers, socio-economic status, constraints, adoption level, knowledge level, aspirational districts, animal husbandry, West Bengal, India

1. Introduction

The rural economy's backbone remains to be agriculture and related activities, particularly raising livestock, which is crucial for the socio-economic advancement, generating revenue, and general well-being of rural farmers of West Bengal. In the rural sector, livestock is crucial for boosting household income and creating productive employment. West Bengal's economic activity has seen fundamental changes throughout the previous few decades. Agriculture and related industries' share in the labour force is dwindling. India has the world's richest animal wealth, yet the productivity of the livestock industry is low [1]. Another explanation for it can be variations in the socio-economic circumstances of the livestock farmers. Studying the socio-economic situation of the rural livestock farmers is important in this context.

Post-Green Revolution, with input-intensive agriculture, India has transformed from a food-deficit nation into a food-surplus one. Animal husbandry is an integral part of rural India's symbiotic system of livestock production and constructs a significant part of the livestock wealth of the country. The socio-economic structure of the nation and the economy are both significantly influenced by animal husbandry. In India, cattle and poultry are an essential component in the rural economy, providing farmers with additional income. More processed foods, especially meat, are becoming more popular in terms of consumer preferences. The sector has enormous potential to increase farmer's income because of its rapid growth. So, the need for livestock rearing for alternative livelihood is the major priority of this day.

India is predicted to raise millions out of poverty due to its high development trajectory. Although India is currently ranked 132 out of 188 nations according to the latest report (Human Development Report, 2022) by United Nations Development Programme, though many of its residents' quality of life does not currently align with this growth story. A detailed examination of the data reveals significant variability in India's living conditions. Significant differences exist inter-state and inter-district levels. India can advance in the Human Development Index by improving the districts that have made relatively less progress towards reaching the important social outcome. The Transformation of Aspirational Districts Programme aims to quickly and efficiently transform these districts. Institutional support (crop insurance, electronic markets, artificial insemination, animal vaccination, etc.) ultimately enables a large number of Indian youths to take up industry-relevant skill training that will help them in securing a better livelihood. It has always been believed that change happens when it begins at the grassroots. Innovative ideas, strategies, practices, and methods should be used to develop the 117 aspirational districts of India with a concentrated effort to transform these districts. In West Bengal, as per NITI Aayog (National Institution for Transforming India), the five Aspirational Districts (Nadia, Murshidabad, Birbhum, Maldah, South Dinajpur) are only under "Lower Gangetic Plains Region" under 15 agro-climatic zones in India.

Black Bengal goat is a very useful small livestock in this area distributed in almost every household in this area. It is also a great source of income for the poor people of this region. Small-scale Goat farming has a very important role in reducing unemployment and poverty. The costs of rearing Black Bengal goats are lower with scientific practices. This creates small-scale enterprise which has tremendous potential in this area in terms of nutritional security, gainful self-employment, and economic upliftment. More than 85% of the population of this region is non-vegetarian and chevon or chicken is preferred by most of the people. Improvement of Black Bengal Goat production is necessary to benefit the rural community and smallholder farmers. India has a large population of goats (16.7% of the world's total) and a diverse genetic group [2]. In India, there are 23 recognised goat breeds [3]. On the other side, West Bengal, with 10.7% of the national total, has the second-highest goat population in the nation (148.90 lakhs) [4]. Poor people in India who live in a variety of climatic conditions depend heavily on goats for their livelihood. Goat keeping creates employment in rural areas at a rate of 4.2% annually [5]. Due to their accessible market demand, goats are seen as fixed deposits for the poorest of the poor, providing funds as and when necessary [6]. Goat management is done with domestic waste and requires only a small cost. Thus, they do not need to incur any more managerial expenses. The primary way that rural women are able to significantly contribute to the financial needs of themselves and their families is through goat rearing. Goat keeping is a highly essential function for women in rural communities.

Based on criteria including poverty, poor health, educational attainment, socio-economic characteristics, etc., the NITI Aayog has designated various districts throughout the nation as aspirational districts in light of the socio-economic development status. Five aspirational districts (Nadia, Murshidabad, Birbhum, Maldah, Dakshin Dinajpur) have been recognised in West Bengal by NITI Ayog. The State can improve its ranking in the Human Development Index by improving these districts that have made substantially less progress toward reaching the important social outcome. The position that each farmer holds in relation to the prevailing average standards, material ownership, social engagement, and other criteria is referred to as their socio-economic status [7]. In light of this context, an effort has been made to study the socio-economic situation and barriers experienced by the farmers in West Bengal's several aspirational districts. Knowledge is the body of information that a person or a society possesses and is an intimate acquaintance with facts [8]. Adoption of any new or enhanced technology or methods is acquired from knowledge. An evaluation of the farmers' existing knowledge and adoption level is necessary prior to the implementation of various entrepreneurship development programs in the study area.

2. Objectives

In the above-said context, certain objectives have been taken in this study. The specific objectives of this study are as follows:

i. To study the socio-economic profile of goat keepers,

ii. To study the rearing challenges in goat rearing under village conditions in various aspirational districts of West Bengal,

iii. To study the adoption level of the farmers, and,

iv. To determine the knowledge level of the farmers in various aspirational districts of West Bengal.

3. Materials and methodology

3.1 Study area selection

As per NITI Aayog, Government of India, the aspirational districts under Lower Gangetic Plains Region in West Bengal are Birbhum, Nadia, Maldah, South Dinajpur, and Murshidabad, where this study was conducted (**Figure 1**).

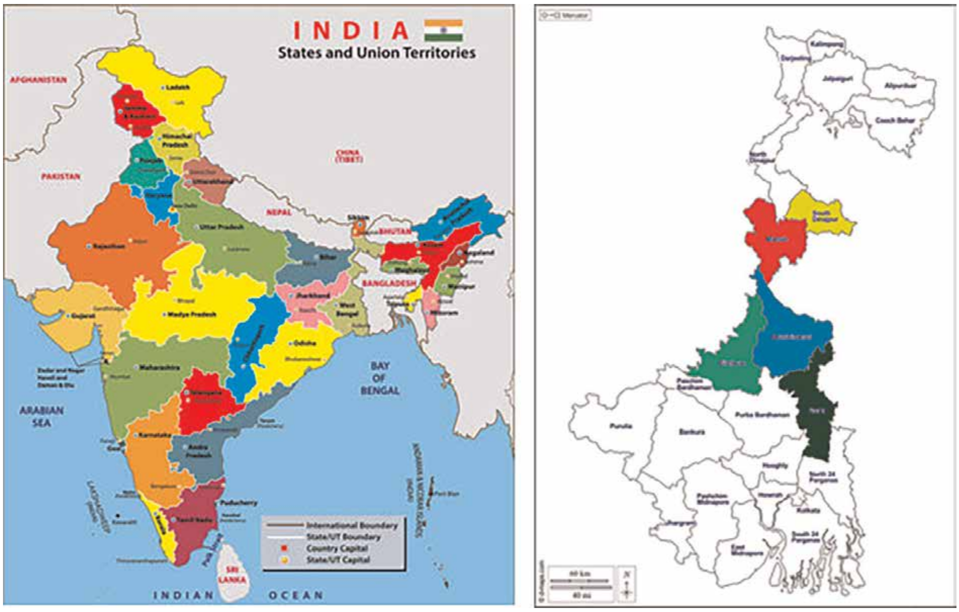

Figure 1.
Study area map. Source: Government of India.

3.2 Sampling design

The five aspirational districts (identified by the NITI Aayog, Government of India) in West Bengal were purposively selected for this study because of their socio-economic condition, level of poverty, poor health, and educational status. Five Blocks were purposively selected from each District. These blocks are Ilambazar from Birbhum District, Haringhata from Nadia District, Bamongola from Maldah District, Kusmandi from South Dinajpur District, and Murshidabad-Jianganj from Murshidabad District. A total of 5000 respondents were randomly selected with a sample of 1000 farmers from each block of each district. The socio-economic status of randomly selected 5000 farmers from the Nadia, Murshidabad, Birbhum, Maldah, and Dakshin Dinajpur districts of West Bengal state was done between January 2020 to September 2022 under the Department of Biotechnology, Government of India, project entitled "Establishment of Biotech KISAN Hub" at West Bengal University of Animal and Fishery Sciences to ascertain the problems of the local farmers for linking available Science and Technology to the farmers of Aspirational Districts of West Bengal to provide a suitable and alternative solution for their better livelihood.

3.3 Methodology used

All the selected variables were assessed either using a pre-existing scale or by creating a schedule. The socio-economic profile of the livestock farmers, including their caste, religion, level of education, family size, occupation, and annual income, has been studied. A pre-tested structured interview schedule was used to get the data. For a better understanding of the results, statistical techniques such as Percentage

Analysis, Chi-Square Test, Standard Error of the Mean, Spearman Correlation Coefficient, and Analysis of Variance (ANOVA) have been measured. These tests were conducted using statistical tool, SPSS (Statistical Package for the Social Sciences), Version 20. Responses were collected between January 2020 to September 2022.

4. Results and discussion

As identified by NITI Aayog, the present study was carried out among 5000 farmers in five aspirational districts of West Bengal (Birbhum, Nadia, Maldah, South Dinajpur, and Murshidabad) in order to evaluate their socio-economic and demographic condition as well as the difficulties they face. This was done in order to identify the issues affecting the local farmers in the area. The analytical studies are shown in the following manner:

4.1 Demographic profile of the farmers

4.1.1 Gender

In the demographic study and in raising livestock, gender is a key factor. It has been noted that the majority of farmers (63.20%) engaged in livestock farming or animal husbandry activities. The Spearman correlation test showed that age, marital status, occupation, caste, and education are all positively and significantly ($P < 0.01$) linked with gender. Age and land ownership have a negative ($P < 0.01$) correlation with gender. This observation differs from the previous findings [9] since their study was conducted in a different location and the farmers were chosen on purpose. As a result, there is a clear contrast between this observation and prior findings.

4.1.2 Age

The data showed that the majority of farmers were in the 30–60 year age bracket, which is the most active age group (67.21%) and that they were most interested in raising goats. According to survey analysis, the percentage of young farmers, or those under 30 years old, was 26.00%, and the percentage of farmers over 60 years old was 6.79% (**Table 1**). The most active respondent groups were 67.25% in Birbhum, 66.98% in Nadia, 67.26% in Maldah, 67.26% in South Dinajpur, and 67.30% in the Murshidabad area. Age and occupation are highly and positively ($P < 0.01$) correlated factors, as are family income, education, and type of housing. Age has a negative ($P < 0.01$) correlation with marital status, religion, family size, and landholding. This result was consistent with previous studies [10, 11].

4.1.3 Religion

The findings showed that Hinduism is practiced by the majority of farmers (61.96%) (**Table 1**). Most respondents (91.37%) in Birbhum district, followed by South Dinajpur district (88.93%) and Maldah district (50.51%), were of the Hindu religion. Additionally, it was noted that the majority of respondents in the districts of Murshidabad (76.01%) and Nadia (54.08%) identified as Muslims. According to the

Characters	Category	Birbhum	Nadia	Malda	South dinajpur	Murshidabad	Overall	Chi-square value
		(%)	(%)	(%)	(%)	(%)	(%)	
Sex	Male	36.76	36.8	36.8	36.79	36.87	36.8	66.64**
	Female	63.24	63.2	63.2	63.21	63.13	63.2	
Age	Young group (up to 30 years)	25.98	26.15	26.02	25.95	25.88	26	94.92**
	Most active group (30–60 years)	67.25	66.98	67.26	67.26	67.3	67.21	
	Elder group (above 60 years)	6.76	6.86	6.73	6.79	6.82	6.79	
Religion	Hindu	91.37	45.92	50.51	88.93	23.99	61.96	160.44**
	Muslim	8.63	54.08	49.49	11.07	76.01	38.04	
Marital status	Married	87.65	87.57	87.56	87.62	87.63	87.61	182.49**
	Unmarried	9.61	9.59	9.64	9.64	9.47	9.59	
	Widow/widower	2.75	2.84	2.79	2.74	2.9	2.8	
Gross family income/ month	Below Rs. 2000	38.04	46.04	12.06	17.98	43.94	32	145.83**
	Rs. 2001–5000	41.96	29.94	59.9	47.98	30.05	41.87	
	Rs. 5001–10,000	14.02	17.99	18.02	24.05	14.02	17.5	
	Rs. 10,001 and above	5.98	6.04	10.03	10	11.99	8.63	
Occupation	Labour	33.14	50.3	16.24	48.81	23.61	34.73	88.44**
	Caste occupation	1.96	2.13	2.03	2.62	3.54	2.43	
	Migrants labour	11.57	13.25	13.96	13.57	18.31	13.98	
	Business	4.31	4.02	3.05	1.19	3.66	3.29	
	Service	4.02	3.2	7.11	2.02	7.83	4.74	
	Cultivation	45	27.1	57.61	31.79	43.06	40.84	
Caste	General	65.39	37.51	53.43	48.33	14.27	44.9	102.94.**
	Schedule caste	14.51	6.51	4.95	26.19	6.06	11.9	
	Schedule tribe	11.57	4.02	2.79	12.38	1.52	6.77	
	Other backward caste	8.53	51.95	38.83	37.98	78.16	41.31	
Education of the respondent	Illiterate	0.98	2.01	5.96	6.19	4.04	3.69	117.28**
	Can read only	20.59	6.04	4.06	17.98	11.62	12.51	
	Can read and write	28.04	9.94	25.89	18.1	16.67	20.02	
	Primary	15.69	15.74	35.91	13.69	20.33	19.88	
	Middle school	15.49	35.98	12.06	12.14	20.08	19.09	
	High school	9.71	22.37	4.06	21.9	17.93	15.08	
	Graduate	9.51	7.93	12.06	10	9.34	9.73	

Characters	Category	Birbhum	Nadia	Malda	South dinajpur	Murshidabad	Overall	Chi-square value
		(%)	(%)	(%)	(%)	(%)	(%)	
Family type	Nuclear family	51.96	15.98	39.34	21.79	9.97	28.87	171.19**
	Joint family	48.04	84.02	60.66	78.21	90.03	71.13	
Family size	Small	51.76	17.16	13.96	20.71	10.61	24.29	221.92**
	Medium	48.24	82.84	86.04	76.9	89.39	75.24	
House type	No house	5.98	6.51	10.03	4.52	6.06	6.56	202.94**
	Hut	4.02	26.86	14.47	14.76	9.97	13.65	
	Kutcha house	25.98	25.33	33.12	35.6	27.27	29.29	
	Mixed house	59.51	35.27	33.5	39.05	49.12	44.01	
	Pucca house	1.96	1.3	4.82	4.05	4.29	3.2	
	Mansion	2.55	4.14	4.06	2.02	3.28	3.17	
Land	No land/land less	16.47	35.98	15.99	22.02	44.95	26.58	105.84**
	Up to 1 hectare	45.98	35.03	32.74	45	20.08	36.41	
	Up to 2 hectares	25.59	26.04	43.4	25	25	28.73	
	Above 2 hectares	11.96	2.37	7.87	7.98	9.97	8.17	
Training received	Not received	15.78	12.9	14.09	18.57	17.93	15.85	89.96**
	Received	84.22	87.1	85.91	81.43	82.07	84.15	
Farm power	No drought animal	72.75	72.78	72.84	72.74	72.73	72.79	117.28**
	1–2 drought animals	19.22	18.22	19.54	19.17	19.19	19.21	
	3–4 drought/1 or more prestige animal	4.8	5.33	4.82	4.76	4.8	4.81	
	5–6 Drought animals/tractors	3.14	3.2	3.17	3.21	3.16	3.2	
Material possession	Bullock cart	30.78	30.77	30.84	30.83	30.81	30.81	145.83**
	Cycle	96.27	96.21	96.32	96.31	95.45	96.27	
	Radio	34.22	34.2	34.26	34.29	34.22	34.26	
	Television	69.71	69.7	72.59	69.76	69.7	69.73	

$^{**}P < 0.01$; $^{*}P < 0.05$.

Table 1.
Demographic and socio-economic characteristics of farmers of aspirational districts of West Bengal (N = 5000).

chi-square test (**Table 1**), the observational difference between the various religions was statistically significant ($P < 0.01$). Due to the location of their studies, this observation differs from the previous findings [10, 12]. Additionally, because the farmers were chosen purposively, any differences or similarities between what has been observed and past results are clearly a natural occurrence.

4.1.4 Marital status

It is observed that altogether, 87.61% of respondents were married, compared to only 9.59% who were single and 2.80% who were widowed. Similar trends were seen in all of the districts. The findings indicated that the majority of respondents (87.65%) in the Birbhum district, followed by those in Murshidabad (87.63%), South Dinajpur (87.62%), Nadia (87.57%), and Maldah (87.56%), were married. According to the chi-square test (**Table 1**), the difference in observation of different marital statuses was statistically significant ($P < 0.01$). The majority of farmers were found to be older than 30 years old, therefore the present result of marital status was a natural occurrence in the study area.

4.1.5 Gross family income

According to the present study, the average farmer's family income is between Rs. 2001 and Rs. 5000 per month, followed by 32% of respondents who earn less than Rs. 2000 per month and 17.50% of respondents who earn between Rs. 5001 and Rs. 10,000 per month. The results also showed that the income of farmers earning more than Rs. 10,001 is quite low (8.63%). In Maldah (59.60%), South Dinajpur (47.98%), and Birbhum district (41.96%), the majority of respondents belong to the monthly income group of Rs. 2001–5000, whereas in Nadia (46%), and Murshidabad district (44%) the majority of respondents belong to the monthly income group of below Rs. 2000. It had been noted that the majority of farmers in the districts of Maldah, South Dinajpur, and Birbhum were comparably more prosperous than those in the other two districts. The difference in value between the different monthly income groups of these farmers had a highly significant effect, according to the chi-square test (**Table 1**) ($P < 0.01$). Given that the majority of farmers (73.87%) had monthly incomes of less than Rs 5000, attention may be focused on helping these farmers to improve their financial situation. Numerous research conducted in this field revealed that the majority of farmers in rural India belonged to low-income categories. However, there are regional and individual differences in economic condition.

4.1.6 Occupation

The majority of farmers (40.84%) work primarily in agriculture, with the remainder working as labourers (34.73%) and migratory workers (13.98%). Aout 43.06% of respondents in Murshidabad district, 57.61% in Maldah district, and 45% in Birbhum district stated that their primary occupation was farming. 50.30% of respondents worked as labour in the Nadia district, while 48.81% did so in the South Dinajpur district. According to the results of the chi-square test (**Table 1**), there were statistically significant differences in the observations of the various occupations. While occupation is negatively correlated with family size, landholding, and training obtained ($P < 0.01$), it is positively correlated with education level, caste, family income, and house type ($P < 0.05$) (**Table 2**). This observation differs with previous studies [13, 14] which may have had a smaller sample size. Such findings were also made by some previous studies [10, 11, 15]. Due to their lower annual income of Rs. 30,000, the farmers' ability to support themselves was at risk, so it was imperative to find an alternative arrangement. The key aim of the policy-making authorities is to take concrete action in this regard while also ensuring the living conditions of these farmers and inclusive growth for them.

	Sex	Age	Marital status	Religion	Occupation	Education Status	Caste	Family type	Family size	family income	Land holding	Training	House type
Sex	1	−0.248**	0.356**	0.111	0.280**	0.361**	0.171**	−0.054	−0.065	0.002	−0.239**	0.003	0.082
Age		1	−0.375**	−0.278**	0.336**	−0.187*	0.132	−0.009	−0.257**	0.179**	−0.307**	0.344**	0.174**
Marital status			1	0.405**	0.011	0.323**	0.182*	0.229**	−0.154	0.308**	0.073	0.064	−0.167
Religion				1	−0.077	0.083	0.069	0.566**	−0.023	0.321**	0.122**	0.119**	−0.098**
Occupation					1	0.832**	0.590**	0.055	−0.373**	0.451**	−0.599**	−0.212**	0.127*
Education status						1	0.530**	0.012	0.010	0.118	−0.125*	0.014	0.107
Caste							1	0.054	0.089	0.112**	−0.265**	0.017	0.109
Family type								1	−0.510	0.455**	0.077	0.089	−0.211**
Family size									1	−0.326**	0.476**	−0.117**	0.389
Family income										1	−0.180**	0.128*	0.086
Land holding											1	−0.054	−0.079
Training												1	0.509
House type													1

**P < *0.01.* *P < *0.05.*

Table 2.
Spearman correlation coefficient of socio-economic characteristics of the farmers of aspirational districts of West Bengal (N = 5000).

4.1.7 Caste

According to the observations, the majority of farmers belong to General Caste (44.9%), followed by OBC (41.31%) and Scheduled Caste (11.9%), only (6.77%) of farmers are ST (**Table 1**). The majority of respondents in the districts of Birbhum (65.39%), Maldah (53.43%), and South Dinajpur (48.33%) fell into the general category. In contrast, 51.95% of respondents in the Nadia district and 78.16% of respondents in the Murshidabad district identified as OBC. According to the results of the chi-square test (**Table 1**), there were statistically significant differences in the observations of the various castes. The results of this study are consistent with some previous studies [10, 12] but they are not consistent with other studies [16], who also claimed that the SC prefers the general trend of goat farming, which may be related to the location of their study.

4.1.8 Educational level

The study of the data showed that only 9.73% of farmers received graduation degree, whereas the majority of farmers can read and write (20.02%), have completed elementary school (19.88%), and middle school (19.09%) (**Table 1**). The findings (**Table 1**) showed that the majority of respondents (28.04%) in the Birbhum district can read and write. Among the sample respondents in the study area, the majority of respondents in the Nadia district (52%) had completed middle school, the majority in the Maldah district (35.91%) had completed primary level, the majority in the South Dinajpur district (21.90%) had completed high school, and the majority in the Murshidabad district (20.08%) had completed middle school. According to the results of the chi-square test (**Table 1**), there were statistically significant differences in the observations of people with different levels of education. Farmers' education levels have a 0.01 significance level positive correlation with caste and a 0.05 significance level negative correlation with land ownership (**Table 2**). This study's majority of farmers (62.8%) had lower educational levels, which is a rather clear finding. Previous studies [10, 12] have noted also a similar tendency. However, some studies [16] have made a different observation, which may have been caused by a different sample size and location.

4.1.9 Family type

Analysis of the data showed that only 28.87% of the farmers were from nuclear families, whereas the majority of farmers (71.13%) came from joint families (**Table 1**). Most families with their entire family reside together in the village area. 90.03% of respondents in the Murshidabad district, 84.02% in the Nadia district, 78.21% in the South Dinajpur district, and 60.66% in the Maldah district belonged to a mixed family. However, the majority of responders (51.96%) came from nuclear families exclusively in the Birbhum district. The variation is extremely significant, according to the chi-square test ($P < 0.01$) (**Table 1**). It appears that family type has a 0.01 significance level of negative correlation with housing type but a 0.01 significance level of positive correlation with family income (**Table 2**). The results show that many economically active joint family members were eager to share more money from raising animals because these activities can support their living as a secondary source of income. Due to larger landholdings and alternative occupations, the annual family income for farmers in joint families is higher than for those in nuclear families overall. The results of previous studies [10, 17] are very similar to the findings of this study.

4.1.10 Family size

In the present study, it was found that 75.24% of farmers had families with a medium size. The remaining farmers (24.29%) had small family sizes. The majority of respondents had medium-sized families in Murshidabad (89.39%), Maldah (86.04%), Nadia (82.84%), and South Dinajpur district (76.90%). Only in Birbhum district (51.76%), most respondents have small families. The difference in value between the varied family sizes of these farmers had a highly significant effect, according to the chi-square test (**Table 1**) ($P < 0.01$).

4.1.11 House types

According to the comprehensive observations, the majority of the farmer's houses were mixed houses (44.01%), followed by kutcha houses (29.59%), and pucca homes (3.20%) (**Table 1**). In every district, the pattern is consistent. Mixed-house respondents were found in Birbhum district 59.51%, Murshidabad district 49.12%, South Dinajpur district 39.05%, Nadia district 35.27%, and Maldah district 33.50%. The chi-square test (**Table 1**) demonstrated that the variation in value between the various housing types for these farmers had a highly significant effect ($P < 0.01$). Given that this is the most common circumstance in rural West Bengal, these results are consistent with other studies [12].

4.1.12 Landholding

The study of the data showed that the majority of farmers (36.41%) had land that was up to 1 hectare in size, while 28.73% had land that was up to 2 hectares, 26.58% had no land, and just 8.17% had land that was beyond 2 hectares. In the districts of Birbhum and South Dinajpur, respectively, 45.78% and 45% of respondents own up to one hectare of land. 43.40% of respondents in the Maldah district have land holdings of up to 2 hectares. While landless farmers predominated (36% of the population) in the districts of Murshidabad (44.95%) and Nadia (35.98%), respectively. The chi-square test revealed that the variation in these farmers' landholding capacities had a highly significant impact ($P < 0.01$). The majority of farmers (62.99%) were found to be either landless or marginal, which offers some hope that they will make enough effort to enhance livestock farming and secure their livelihood. These results were supported by previous findings [12]. Different opinions may exist in this regard, which may be caused by the impact of different regions.

4.1.13 Training

According to the present study, the majority of farmers (84.15%) had received training in animal husbandry, with only 15.85% of farmers receiving no such training (**Table 1**). According to the results of the chi-square test, the variations are statistically significant ($P < 0.01$) (**Table 1**). Giving training is an important strategy to help the agricultural community find alternative sources of income, as seen in the present study, where training obtained was positively correlated with age and religion at the 0.01 significance level (**Table 2**), as well as with family income at $P < 0.05$ level

(**Table 2**). It was evident in the present survey that livestock can help farmers make a living.

4.1.14 Farm power

The analysis of the data showed that the majority of farmers (72.79%) did not have any drought animals, while 19.21% of farmers did have one or two (**Table 1**). The majority of respondents in Birbhum (72.75%), Nadia (72.78%), Maldah (72.84%), South Dinajpur (72.74%), and Murshidabad district (72.73%) had no drought animals, while only a small percentage had one or two drought animals. According to the chi-square test (**Table 1**), the farmers' varying farm power values had a very significant impact ($P < 0.01$).

4.1.15 Material possession

In the present study, it was found that 69.73% of farmers had televisions in their homes, with the majority of farmers (96.27%) having their own cycles(**Table 1**). In the Birbhum district, 96.27% of respondents stated having access to a cycle, while 69.71% reported having television and 34.22% having radio. In the Nadia district, 96.21% of participants answered owning a cycle, while 69.70% noted owning a television and 34.20% claimed owning a radio. In the Maldah district, 96.32% of respondents stated owning a cycle, while 72.59% reported owning a television and 34.26% reported owning a radio. In the South Dinajpur district, 96.31% of respondents stated owning a cycle, while 69.76% claimed owning a television and 34.29% claimed owning a radio. In the Murshidabad district, 95.45% of respondents stated owning a cycle, while 69.70% stated owning a television and 34.22% stated owning a radio. According to the chi-square test (**Table 1**), these farmers' disparate material possessions had a highly significant impact ($P < 0.01$).

4.2 Socio-economic status

Table 3 has summarised the analysis of the 5000 livestock farmers' economic conditions in West Bengal's five aspirational districts (Nadia, Murshidabad, Birbhum, Maldah, and Dakshin Dinajpur). Additionally, analysis of variance was performed too to determine the effects of the kind of dwelling, ownership of land, employment, and training in animal husbandry techniques. According to the survey, farmers with larger landholdings have considerably ($P < 0.01$) higher monthly family incomes from agriculture, animal husbandry, and other sources (service/business) than those with smaller landholdings. According to the survey, farmers with mixed-house types, pucca houses, or mansions make significantly ($P < 0.01$) more money from agriculture, animal husbandry, or other sources (service/business) for their families than those with no homes or kutcha houses. Farmers with mansions make an average monthly income of Rs. 10,398.15, compared to Rs. 3123.84 for farmers without homes. It demonstrates that those with superior economic returns also possess better material goods. An important factor that affects the farmer's financial growth is training. When compared to those who received no training, the agricultural community's economic returns were considerably ($P < 0.01$) higher. Another significant factor that affects the farmer's economic growth is the farmer's occupation (**Table 4**). When compared to those who work in agriculture (Rs. 6849.30), the service sector (Rs. 11,004.85), the

Different factors		From agriculture (Rs)	From animal husbandry (Rs)	From other (service/ businesses) (Rs)	Total income (Rs)
Overall		2024.95 ± 16.05	971.98 ± 12.36	4059.62 ± 12.66	7056.55 ± 13.63
Districts	Birbhum	2240.52 ± 19.23	1075.45 ± 14.81	4055.34 ± 15.70	7371.31 ± 16.91
	Nadia	2018.09 ± 15.88	968.68 ± 12.22	4237.99 ± 12.41	7224.76 ± 13.36
	Maldah	2026.23 ± 16.148	972.59 ± 12.46	3849.84 ± 12.91	6848.66 ± 13.91
	South Dinajpur	1857.67 ± 13.13	891.68 ± 10.11	4086.87 ± 6.59	6836.23 ± 7.09
	Murshidabad	1930.79 ± 13.74	926.78 ± 10.58	4054.66 ± 10.38	6912.23 ± 11.18
Sex	Male	2260.19 ± 19.54	1068.20 15.05	4949.50 ± 15.95	7311.29 ± 17.18
	Female	1698.09 ± 4.69	866.02 ± 3.61	2884.22 ± 4.00	5448.33 ± 4.31
Age	Young group (up to 30 years)	2046.49 ± 17.10	982.32 ± 13.16	3849.84 ± 13.67	6878.65 ± 14.72
	Most active group (30–60 years)	2285.33 ± 19.85	1290.54 ± 15.28	4866.41 ± 16.61	8442.28 ± 17.89
	Elder group (above 60 years)	1977.73 ± 15.26	949.31 ± 11.75	4153.23 ± 11.90	7080.26 ± 12.82
Religion	Hindu	2228.85 ± 18.93	1069.85 ± 14.58	4234.82 ± 15.44	7533.53 ± 16.63
	Muslim	1671.90 ± 4.33	802.51 ± 3.33	3678.18 ± 23.95	6152.60 ± 25.80
Marital status	Married	2127.54 ± 17.71	1021.22 ± 13.63	4042.33 ± 14.43	7191.09 ± 15.54
	Unmarried	1996.30 ± 15.57	537.73 ± 11.99	3613.31 ± 12.15	6147.34 ± 13.09
	Widow/widower	1836.46 ± 12.82	910.56 ± 9.87	3178.49 ± 4.26	5925.51 ± 4.59
Family type	Nuclear family	1467.56 ± 3.72	749.01 ± 2.86	4495.56 ± 3.09	6712.13 ± 3.32
	Joint family	2431.48 ± 20.15	1167.11 ± 15.52	4234.82 ± 16.89	7833.41 ± 18.19
Education	Illiterate	2041.58 ± 16.79	873.85 ± 12.93	2615.60 ± 13.42	5531.02 ± 14.45
	Farmers' education up to middle school (class 10)	2107.28 ± 17.40	1069.85 ± 13.40	3926.84 ± 14.18	7103.97 ± 15.27
	Farmers' education more than middle school (class 10)	1931.98 ± 14.44	980.85 ± 11.12	7356.37 ± 11.14	10269.19 ± 12.00
Training	Training received	2191.86 ± 18.62	1052.09 ± 14.34	4471.04 ± 15.19	7714.99 ± 16.36
	Training not received	1702.03 ± 5.73	719.72 ± 4.41	4311.82 ± 5.55 (3606)	6733.57 ± 5.98 (3606)
Occupation	Labour	598.77 ± 2.41	480.85	2054.22	3123.84
	Caste occupation	1655.25 ± 3.95	840.12 ± 3.04	5002.28 ± 6.65 (1040)	7497.65 ± 7.17 (1040)
	Migrants labour	1702.03 ± 5.13	719.72 ± 3.95	4311.82 ± 3.59	6733.57 ± 3.87
	Business	1902.86 ± 13.43	849.19 ± 10.34	5148.31 ± 14.20	7900.36 ± 15.30

Different factors		From agriculture (Rs)	From animal husbandry (Rs)	From other (service/ businesses) (Rs)	Total income (Rs)
	Service	1931.98 ± 14.35	980.85 ± 11.05	8092.02 ± 10.89	11004.85 ± 11.72
	Cultivation	2105.62 ± 17.13	1055.14 ± 13.19	3688.54 ± 13.92 (1750)	6849.30 ± 15.00 (1750)
Caste	General	2155.15 ± 18.01	1040.72 ± 13.87	5002.28 ± 14.68 (1924)	8198.15 ± 15.82 (1924)
	Schedule caste	1958.33 ± 14.65	719.72 ± 11.28	4311.82 ± 11.39	6989.87 ± 12.27
	Schedule tribe	1722.12 ± 6.70	934.18 ± 5.16	3533.11 ± 11.98	6189.41 ± 12.90
	Other backward caste	1731.68 ± 8.02	880.48 ± 6.18	4865.17 ± 4.75	7477.33 ± 5.11
House Type	No house	588.77 ± 2.20	480.85 ± 1.69	2054.22 ± 2.22	3123.84 ± 2.40
	Hut	1805.62 ± 12.52	905.14 ± 9.64	2988.75 ± 3.89	5699.51 ± 4.19
	Kutcha house	1958.33 ± 14.96	719.72 ± 11.52	4001.82 ± 11.65	6679.87 ± 12.54
	Mixed house	1722.12 ± 7.94	934.18 ± 6.11	3533.11 ± 28.40	6189.41 ± 30.59
	Pucca house	1931.47 ± 14.04	988.25 ± 10.81	5837.17 ± 10.63	8756.89 ± 11.45
	Mansion	2155.15 ± 18.32	1040.72 ± 14.11	7202.28 ± 14.94	10398.15 ± 16.09
Land Holding	No land/land less	1029.25 ± 2.68	719.72 ± 2.07	3012.21 ± 1.99	4761.17 ± 2.15
	Up to 1 hectare	1698.24 ± 4.83	934.18 ± 3.72	3533.11 ± 3.28	6165.53 ± 3.53
	Up to 2 hectares	2031.45 ± 16.49	1018.25 ± 12.69	5837.17 ± 13.17	8886.87 ± 14.18
	Above 2 hectares	2550 ± 20.4	1040.72 ± 15.75	6801.128 ± 17.17	10391.85 ± 18.49

Table 3.
Monthly economic return (in rupees) (Mean ± SEM) of the farmers of aspirational districts of West Bengal (N = 5000).

business sector (Rs. 7900.36), or as labour (Rs. 3123.84), people who are employed in these occupations are thought to have greater total monthly incomes ($P < 0.01$) (**Table 5**).

4.3 Adoption level of the farmers in the aspirational districts

4.3.1 Adoption index of the farmers in the aspirational districts

With regard to improved farm practices of animal husbandry, such as vaccination against contagious diseases, cultivation of green fodder, deworming for parasitic disease, feeding of concentrate mixture, feeding of green fodder, feeding of urea and molasses treated straw, feeding of colostrum to new-born kid, castration by bradizzo castrator, value addition of milk and meat, Adoption Index (mean and standard error of mean [SEM]) [18] has been generated among the farmers in the Aspirational Districts of West Bengal. Analysis of variance in respect of gender, age of the farmers, religion, marital status, occupation, caste, education, family type, family size, house type, training received, and land-holding capacities have been assessed and depicted in **Table 6**.

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SOV	df	From agriculture	From animal husbandry	From other (service/businesses)	Total income	From agriculture	From animal husbandry	From other (service/businesses)	Total income
		Mean square				*F* value			
Sex	1	26.8	44.8	62.7	44.8	1.14	1.62	5.56**	1.14
Age	2	81.1	57.9	46.2	51.8	3.32	1.12	4.10*	1.32
Religion	1	68.8	56.7	23.5	47.6	2.89	1.81	1.99	1.21
Marital status	2	78.2	39.5	125.9	81.13	3.64*	1.03	11.87**	2.76
Family type	1	96.7	67.5	109.3	117.4	6.98**	2.84	9.70**	2.99
Education	2	55.9	78.6	158.4	104.9	2.52	2.48	17.38**	2.67
Training	1	63.7	187.43	197.0	142.29	2.54	6.89**	14.89**	3.66*
Occupation	5	164.3	93.7	233.5	169.7	5.10*	3.05	29.55**	4.02**
Caste	3	66.4	38.7	22.1	32.21	1. 49	1. 80	1.79	0.87
House Type	5	89.34	88.71	212.31	133.3	3.97*	3.14*	19.51**	3.39*
Land Holding	3	761.6	167.32	81.4	310.5	28.52**	6.40**	7.35**	7.90**
Error	5424	32.654	29.576	13.026	28.226				

**P < 0.01; *P < 0.05.

Table 4.
ANOVA of monthly economic return of different category of the farmers under aspirational districts of West Bengal.

Category	Different factors	Adoption index	Adoption level (%)			
		(Mean ± SEM)	Low	Medium	High	Chi square value
			(<5.00)	(>5.00–6.5)	(>6.5)	
Overall		5.95 ± 1.05	58.35	32.80	8.85	72.14**
Districts	Birbhum	5.57 ± 0.93	62.10	28.30	9.60	60.44**
	Nadia	5.20 ± 1.16	57.86	31.46	10.67	
	Maldah	6.02 ± 1.01	60.66	29.37	9.96	
	South Dinajpur	6.07 ± 0.99	46.97	39.60	13.43	
	Murshidabad	6.01 ± 1.03	54.08	34.29	11.63	
Age	Young group (up to 30 years)	6.09 ± 0.92	52.71	35.31	11.98	82.49**
	Most active group (30–60 years)	5.90 ± 1.03	56.45	32.52	11.03	
	Elder group (above 60 years)	5.88 ± 0.93	55.07	33.55	11.38	
Religion	Hindu	5.86 ± 1.01	58.28	31.15	10.57	75.33**
	Muslim	5.12 ± 1.13	57.83	31.49	10.68	
Marital Status	Married	5.41 ± 0.96	58.67	30.86	10.47	64.84**
	Unmarried	5.19 ± 1.05	60.35	29.61	10.04	
	Widow/widower	5.45 ± 1.28	58.36	31.09	10.55	
Occupation	Labour	5.99 ± 0.72	46.59	39.88	13.53	68.94**
	Caste occupation	5.06 ± 1.00	61.34	28.87	9.79	
	Migrants labour	5.46 ± 0.98	56.95	38.40	4.65	
	Business	5.04 ± 1.10	61.49	28.75	9.75	
	Independent	5.55 ± 0.89	57.60	31.66	10.74	
	Cultivation	5.95 ± 1.09	62.18	28.24	9.58	
Caste	General	5.82 ± 1.02	58.59	30.92	10.49	67.28**
	Schedule caste	5.52 ± 0.97	57.83	31.49	10.68	
	Schedule tribe	5.37 ± 0.88	58.97	30.64	10.39	
	Other backward caste	4.74 ± 1.06	63.78	27.04	9.17	
Education of the farmers	Illiterate	5.04 ± 1.05	61.49	28.75	9.75	74.44**
	Can read only	5.29 ± 1.02	59.58	30.18	10.24	
	Can read and write	5.41 ± 1.06	58.67	30.86	10.47	
	Primary	5.72 ± 1.02	56.30	32.63	11.07	
	Middle school	5.85 ± 1.04	55.30	33.37	11.32	
	High school	6.09 ± 0.86	53.47	34.74	11.79	
	Graduate	6.22 ± 1.12	60.12	29.78	10.10	

Category	Different factors	Adoption index	Adoption level (%)			
		(Mean ± SEM)	Low	Medium	High	Chi square value
			(<5.00)	(>5.00–6.5)	(>6.5)	
Family type	Nuclear family	5.85 ± 1.12	55.33	33.35	11.31	104.22**
	Joint family	5.96 ± 1.06	49.97	37.36	12.67	
Family Size	Small	5.66 ± 0.99	47.17	39.45	13.38	79.94**
	Medium	5.59 ± 1.00	47.82	38.96	13.22	
	Large	5.57 ± 1.11	48.01	38.82	13.17	
House Type	No house	5.49 ± 0.97	42.22	43.14	14.63	47.84**
	Hut	5.72 ± 0.92	43.81	41.96	14.23	
	Kutcha house	5.55 ± 1.08	48.20	38.68	13.12	
	Mixed house	6.02 ± 1.01	43.81	41.96	14.23	
	Pucca house	6.09 ± 0.87	43.16	42.44	14.40	
	Mansion	5.32 ± 1.04	50.34	37.08	12.58	
Land Holding	No land/land less	5.54 ± 1.07	48.29	38.61	13.10	77.74**
	Up to 1 hectare	5.92 ± 1.09 (1560)	44.74	41.26	14.00	
	Up to 2 hectares	6.45 ± 1.09	39.77	44.97	15.26	
	Above 2 hectares	7.63 ± 0.92	34.35	49.02	16.63	
Training	Training received	7.89 ± 1.08	42.24	39.82	17.94	87.22**
	Training not received	5.42 ± 1.01	56.95	38.40	4.65	

***P < 0.01; *P < 0.05.*

Table 5.
Adoption index (mean ± SEM) and adoption level of the farmers of aspirational districts of West Bengal (N = 5000).

It had been observed that education, training received, occupation and landholding had highly ($P < 0.01$) significant effect on adoption index. It had been appeared that adoption index among the farmers of South Dinajpur district (6.14 ± 0.99) was significantly higher than the other four districts namely Maldah (6.11 ± 1.01), Murshidabad (6.01 ± 1.03), Birbhum (5.98 ± 0.93), and Nadia (5.35 ± 1.16). The result indicated that the farmers of South Dinajpur district were more adapted to improved animal husbandry practices. The farmers who were graduate or had higher educational degree were having significantly ($P < 0.01$) higher adoption index (7.41 ± 1.09) in comparison to those with lower educational level. Similarly, who were worked as labour and engaged in cultivation having significantly ($P < 0.01$) higher adoption index than other occupations.

Farmers, who had received training, were significantly ($P < 0.01$) higher adoption index (8.65 ± 1.06) in comparison to those who had not received any training (6.54 ± 1.08). It was clear that the farmers who had received training were more

SOV	df	Mean square from	F value
Sex	1	10.92	1.16
Age	2	8.07	0.86
Religion	1	10.13	1.07
Marital status	2	15.00	1.59
Family type	1	12.98	1.38
Education	2	44.49	4.72**
Training	1	130.51	13.84**
Occupation	5	43.54	4.62**
Caste	3	18.05	1.91
House type	5	15.28	1.62
Land holding	3	40.83	4.33**
Error	4254	9.43	
**P < 0.01; *P < 0.05.			

Table 6.
ANOVA of adoption index of different category of the farmers of aspirational districts of West Bengal.

familiar with new methods of animal husbandry. These farmers, therefore, favored the deployment of improved technology. The adoption of more advanced technologies was chosen by the farmers in terms of land-holding patterns.

The adoption index of farmers with land holdings larger than 2 acres was considerably ($P < 0.01$) higher (8.35 ± 0.93) than that of landless (6.34 ± 1.02), marginal (7.81 ± 1.07), and small farmers (6.89 ± 1.06) groups in the study. Farmers with land, especially agricultural land larger than 2 acres, preferred to raise animals as a form of secondary income. Their ability to raise livestock scientifically required improved technology, which is why the adoption rate was comparatively higher. Other variables like age, religion, education, caste, marital status, family size, and type of housing had no significant impact on those farmers' adoption rates.

4.3.2 Adoption level of the farmers in the aspirational districts

A major indicator of how important the improved technology was to these farmers was the adoption rate. The value was shown in **Table 5** and the adoption level was divided into three categories: low, medium, and high. In comparison to the other four districts, it was found that the majority of farmers in Birbhum district (67.07%) had a larger percentage of low adoption levels. Unmarried person engaged in cultivation (66.27%) were also having higher frequency of low-level adoption in comparison to married person (64.45%). Farmers of other backward caste were having higher frequency of low level of adoption (67.46%) in relation to other caste (General caste 62.35%). Illiterate (67.25%) persons were also having higher frequency of low-level adoption in comparison to higher educated persons (65.37%).

The chi-square test (**Table 5**) found that the difference in value in adoption level of these farmers based on different category had a highly significant effect ($P < 0.01$). The adoption of technology by mainly small and marginal farmers in the underdeveloped districts (Aspirational Districts) of West Bengal was the prime focus of the

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Factors	Districts	Age	Religion	Marital status	Occupation	Caste	Education of the farm ers	Family type	Training	House type	Land holding	Adoption index
Districts	1.00	−0.158*	0.142*	−0.640**	0.383**	0.301**	−0.628**	0.08	0.09	0.234**	−0.12	0.10
Age		1.00	0.01	0.164**	−0.11	−0.396**	0.150*	0.12	0.11	−0.03	0.10	0.07
Religion			1.00	−0.269**	0.403**	0.127*	0.333**	0.418**	0.11	−0.07	0.03	0.362**
Marital status				1.00	−0.358**	−0.223**	0.528**	−0.12	0.10	−0.218**	0.317**	−0.06
Occupation					1.00	0.444**	0.01	0.353**	0.245**	−0.01	0.353**	0.440**
Caste						1.00	−0.153*	0.07	−0.08	0.07	0.203**	0.162*
Education of the farmer							1.00	0.267**	0.41**	−0.337**	0.401**	0.273**
Family type								1.00	0.11	0.06	0.125*	0.356**
Training									1.00	−0.05	0.248**	0.256**
House type										1.00	−0.323**	−0.269**
Land holding											1.00	0.373**
Adoption index												1.00

**P < 0.01; *P < 0.05.

Table 7.
Spearman correlation of adoption index with different factors among the farmers of aspirational districts of West Bengal (N = 5000).

present study. The result had showed low level of adoption among these farmers who indicated their lacking in application of improved animal husbandry practices. The present study conducted mainly with small and marginal farmers in the underdeveloped districts (Aspirational Districts) of West Bengal.

4.3.3 Relationship between independent variables with adoption level of farmers in the aspirational districts

Table 7 provides the correlation coefficients for each personal and socio-economic characteristic with the respondents' adoption level. Overall, it was found that seven independent variables—religions, occupations, education, family type, house type, land holding, and training—showed highly significant correlation ($P < 0.01$) with the adoption level of farmers in five Aspirational Districts in West Bengal. Caste, however, showed a significant correlation with this variable at the 0.05 level of probability. The adoption rate of farmers in five aspirational districts in West Bengal was not significantly correlated with the other three variables, district, age, or marital status. Marital status had a negative correlation with adoption index, but it was not statistically significant.

4.3.4 Adoption level of different technologies among the farmers in the aspirational districts

Adoption level of different technologies is depicted here (**Table 8** and **Figure 2**). Hence in future days, comprehensive farmers' trainings and awareness programmes need to be generated for improvement of their livelihood through livestock rearing. In South Dinajpur vaccination (82.14%) had highest adoption level followed by Murshidabad district (75.96%) and Nadia districts (73.97%), Maldah (71.97%) and Birbhum (67.68%). Cultivation of Green fodder adoption level have higher frequency in Murshidabad (37.12%) in comparison to other districts namely Maldah (36.69%), Birbhum (35.73%), Nadia (35.72%), and South Dinajpur (26.69%). Value addition of

Category	Birbhum	Nadia	Maldah	South Dinajpur	Murshidabad	Overall
	(%)	(%)	(%)	(%)	(%)	(%)
Vaccination against contagious disease	67.94	73.96	71.95	82.14	76.01	74.14
Deworming for parasitic control	66.08	64.02	66.5	71.67	67.93	67.19
Cultivation of green fodder	35.88	35.74	36.68	26.67	37.12	34.42
Feeding of green fodder	36.18	29.23	32.23	39.52	36.49	34.8
Feeding of concentrate mixture	43.82	26.51	34.14	52.98	42.05	40.09
Feeding of colostrum to newborn kid	27.84	20	26.78	30.83	28.16	26.74
Feeding of urea and molasses treated straw	24.02	18.22	23.35	23.93	24.49	22.82
Castration by bradizzo castrator	30	25.33	25.13	34.05	26.39	28.31
Value addition of milk and meat	21.96	25.56	26.14	33.1	32.2	27.51

Table 8.
Adoption of different technologies among the farmers of aspirational districts of West Bengal (N = 5000).

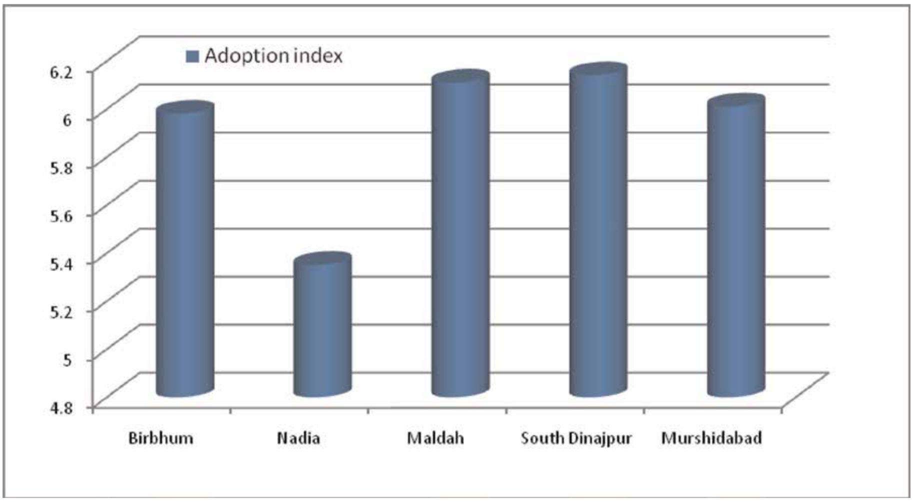

Figure 2.
Adoption index among the farmers of different aspirational districts (developed by the authors).

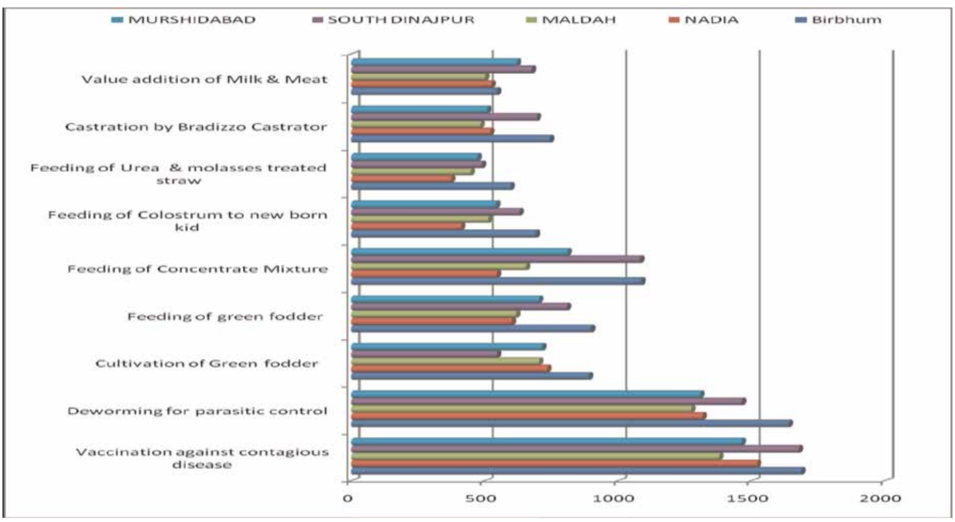

Figure 3.
Adoption of different technologies among the farmers of aspirational districts of West Bengal (developed by the authors).

Milk and Meat frequency have higher adoption level in South Dinajpur Districts (33.10%) followed by Murshidabad (32.19%), Maldah (26.15%), Nadia (25.55%), and Birbhum (21.88%) (**Figure 3**).

4.4 Knowledge level of the farmers in the aspirational districts

4.4.1 Knowledge index of the farmers in the aspirational districts

Knowledge Score (Mean and SEM) generated using standard practice [19] among the farmers in the Aspirational Districts of West Bengal in relation to improved farm

Category	**Different factors**	**Knowledge score**	**Knowledge level (%)**			
		(Mean ± SEM)	**Low**	**Medium**	**High**	**Chi square value**
			(<30.00)	**(>30.00–35)**	**(>35)**	
Overall		34.98 ± 3.22	59.15	31.75	9.10	64.14**
Districts	Birbhum	35.07 ± 2.85	62.10	28.30	9.60	62.85**
	Nadia	37.37 ± 3.55	57.86	30.00	12.00	
	Maldah	34.18 ± 3.09	60.00	30.00	9.96	
	South Dinajpur	30.16 ± 3.03	48.00	39.60	12.00	
	Murshidabad	33.51 ± 3.15	54.08	34.29	11.63	
Age	Young group (up to 30 years)	34.09 ± 2.82	53.29	34.88	11.83	104.33**
	Most active group (30–60 years)	33.85 ± 3.15	53.66	34.60	11.74	
	Elder group (above 60 years)	34.28 ± 2.85	53.03	35.08	11.90	
Religion	Hindu	34.78 ± 3.09	52.34	35.59	12.07	74.28**
	Muslim	33.45 ± 3.46	54.16	34.23	11.61	
Marital status	Married	32.89 ± 2.94	54.93	33.65	11.42	57.58**
	Unmarried	33.45 ± 3.21	54.16	34.23	11.61	
	Widow/widower	34.74 ± 3.92	52.40	35.55	12.06	
Occupation	Labour	33.97 ± 2.20	53.45	34.76	11.79	59.66**
	Caste occupation	35.01 ± 3.06	52.03	35.82	12.15	
	Migrants labour	33.63 ± 3.00	61.18	26.46	12.37	
	Business	32.22 ± 3.37	55.85	32.97	11.18	
	Independent	34.08 ± 2.72	53.30	34.87	11.83	
	Cultivation	35.04 ± 3.34	51.98	35.85	12.16	
Caste	General	34.85 ± 3.12	52.25	35.66	12.10	64.65**
	Schedule caste	33.36 ± 2.97	54.29	34.13	11.58	
	Schedule tribe	32.98 ± 2.69	54.81	33.75	11.45	
	Other backward caste	35.19 ± 3.24	51.78	36.01	12.21	
Education of the farmers	Illiterate	35.55 ± 3.21	51.29	36.37	12.34	58.36**
	Can read only	33.61 ± 3.12	53.94	34.39	11.67	
	Can read and write	33.65 ± 3.24	53.89	34.43	11.68	
	Primary	33.07 ± 3.12	54.68	33.84	11.48	
	Middle school	33.76 ± 3.18	53.74	34.54	11.72	
	High school	34.03 ± 2.63	53.37	34.82	11.81	
	Graduate	36.2 ± 3.43	50.40	37.04	12.56	

Category	Different factors	Knowledge score	Knowledge level (%)			
		(Mean ± SEM)	Low	Medium	High	Chi square value
			(<30.00)	(>30.00–35)	(>35)	
Family type	Nuclear family	33.75 ± 3.43	53.75	34.53	11.71	98.25**
	Joint family	35.1 ± 3.24	53.27	34.89	11.84	
Family size	Small	33.77 ± 3.03	60.28	29.85	9.87	58.22**
	Medium	35.45 ± 3.06	54.16	34.23	11.61	
House type	No house	33.28 ± 3.40	54.40	34.05	11.55	44.22**
	Hut	33.65 ± 2.97	53.89	34.43	11.68	
	Kutcha house	34.06 ± 2.82	53.33	34.85	11.82	
	Mixed house	34.77 ± 3.30	52.35	35.58	12.07	
	Pucca house	36.5 ± 3.09	49.98	37.35	12.67	
	Mansion	37.1 ± 2.66	49.16	37.96	12.88	
Land holding	No land/land less	33.36 ± 3.18	54.29	34.13	11.58	47.64**
	Up to 1 hectare	34.52 ± 3.27	52.70	35.32	11.98	
	Up to 2 hectares	36.02 ± 3.34	51.88	35.93	12.19	
	Above 2 hectares	36.24 ± 3.34	50.34	37.08	12.58	
Training	Training received	33.21 ± 2.82	62.10	28.30	9.60	45.88**
	Training not received	37.07 ± 3.30	52.71	35.31	11.98	

**P < 0.01; *P < 0.05.

Table 9.
Knowledge score (mean ± SEM) and knowledge level of the farmers of aspirational districts of West Bengal (N = 5000).

practices of animal husbandry had been depicted in **Table 9**. **Table 10** shows the analysis of variance by religion, age of the farmers, marital status, caste, occupation, and education of the farmers, as well as by family size, family type, land holding capacities, and house type. All the factors, including districts, marital status, age of the farmers, occupation, religion, caste, education, family type, house type, family size, and land holding capacities, had not been shown to have a significant impact on knowledge scores (**Table 10**). However, it showed that South Dinajpur had the lowest Knowledge Score (30.16 ± 3.03) and Nadia district had the highest knowledge score (37.37 ± 3.55) among farmers, compared to Birbhum (35.07 ± 2.85), Maldah (34.18 ± 3.09), and Murshidabad (33.51 ± 3.15).

The findings suggested that farmers in the Nadia district knew more about modern methods of animal husbandry. More intriguingly, it was found that farmers with agricultural land holdings larger than 2 acres (36.24 ± 3.34), and Pucca Houses (36.5 ± 3.09), or mansions (37.1 ± 2.66), had higher knowledge level about animal husbandry. These results were regarded as a natural phenomenon of a higher knowledge score since they considered modern technology. Farmers who had land, especially agricultural land area larger than 2 acres, and were financially stable, preferred raising animals as a source of additional family income. Improved technology for

SOV	df	Mean square from	F value
Sex	1	12.96	1.13
Age	2	12.42	1.08
Religion	1	20.03	1.75
Marital status	2	41.40	3.62
Family type	1	8.44	0.74
Education	2	26.64	2.33
Training	1	5.19	0.45
Occupation	5	12.76	1.11
Caste	3	26.15	2.28
House type	5	25.37	2.22
Land holding	3	27.01	2.36
Error	4254	11.45	

**P < *0.01* *P < *0.05.*

Table 10.
ANOVA of knowledge score of different category of the farmers of aspirational districts of West Bengal.

raising livestock scientifically is crucial for increasing economic gain, because of that their Knowledge Score was comparatively higher. The Knowledge Score of those farmers was unaffected by other variables such as age, religion, occupation, education, caste, marital status, family size, or type of housing.

4.4.2 Knowledge level of the farmers in the aspirational districts

Level of knowledge (**Table 9**) is an important factor to assess utilisation of the improved technology among farmers. The farmers engaged in livestock farming were classified into three level of knowledge namely low (<30), medium (>30 –35), and high (>35). The result of knowledge level of these three groups namely low, medium, and high and the value was depicted in **Table 9**.

It had been observed that majority of farmers in Birbhum district (62.10%) were having a higher percentage of low knowledge levels in comparison to other four districts. In Nadia districts (57.86%) farmers had low level of knowledge followed by medium (30%) and high (12%) level of knowledge in improved livestock farming practices. In Maldah district (60%) farmers had low level of knowledge followed by medium (30%) and high (9.96%) level of knowledge in improved livestock farming practices. Most interestingly, the farmers of South Dinajpur district had less low level of knowledge (48%) but higher medium (39.60%) and high (12%) level of knowledge which indicated that these farmers were befitted for improved animal farming practices.

In comparison to other farmers, those who owned agricultural land larger than 2 acres and Pucca House or another mansion tended to have higher or medium levels of knowledge about animal husbandry. In addition to the farmers' education, financial stability was a key aspect in learning information. The chi-square test (**Table 9**) showed a highly significant effect ($P < 0.01$) of the difference in value in knowledge level of these farmers based on distinct categories (**Table 10**).

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Factors	Districts	Age	Religion	Marital status	Occupation	Caste	Education of the farm women	Family type	Training	House type	Land holding	Knowledge level
Districts	1.0	−0.16*	0.142*	−0.640**	0.383**	0.301**	−0.628**	0.01	−0.290**	0.234**	−0.1	−0.137*
Age		1.0	0.02	0.164**	−0.1	−0.396**	0.150*	0.1	0.1	0.01	0.1	0.001
Religion			1.0	−0.269**	0.403**	0.127*	0.333**	0.418**	0.170**	−0.1	0.0	−0.336**
Marital status				1.0	−0.358**	−0.223**	0.528**	−0.1	0.245**	−0.218**	0.317**	0.220**
Occupation					1.0	0.444**	0.01	0.353**	0.1	0.0	0.353**	−0.242**
Caste						1.0	−0.153*	0.1	0.01	0.1	0.203**	−0.109
Education of the farm women							1.0	0.267**	0.407**	−0.337**	0.401**	−0.108
Family type								1.0	0.608**	0.1	0.125*	−0.258**
Training									1.0	−0.1	0.248**	0.358**
House Type										1.0	−0.323**	0.094
Land Holding											1.0	0.024
Knowledge level												1.0

*P < 0.05; **P < 0.01.

Table 11.
Spearman correlation of knowledge level of the farmers of aspirational districts of West Bengal.

In order to create an effective work plan for a sustainable livelihood through livestock rearing, it was necessary to examine the level of livestock farming expertise among the farmers in these aspirational districts. The result showed low level of knowledge among these farmers which indicate their lacking in application of improved animal husbandry practices.

4.4.3 Relationship between independent variables with the knowledge level of farmers

Table 11 provides the correlation coefficients for each personal and socio-economic characteristic with the respondent's knowledge level (**Figure 4**). The study indicated that, generally, out of 11 independent variables, family type, occupation, and religion showed highly negative correlation ($P < 0.01$) with knowledge level of farmers in five districts (**Figure 5**). The two variables marital status and training showed highly positive correlation whereas the remaining variables namely, age, caste, education, house type, and land holding did not establish any significant

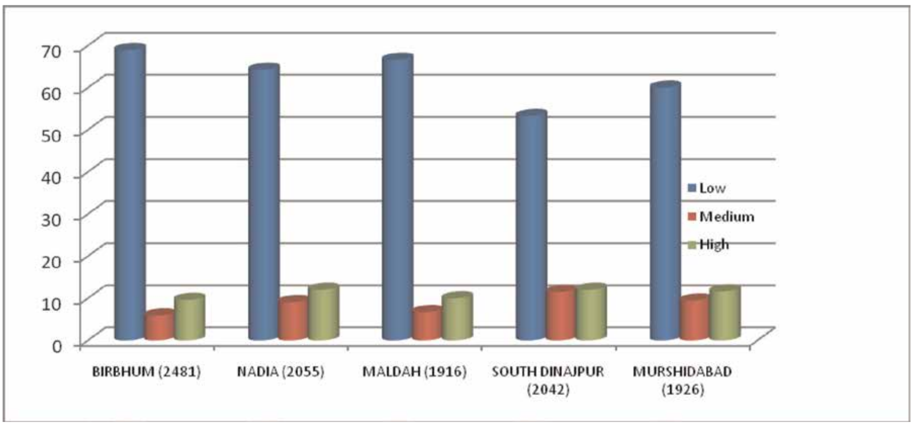

Figure 4.
Knowledge level among the farmers of different aspirational districts (developed by the authors).

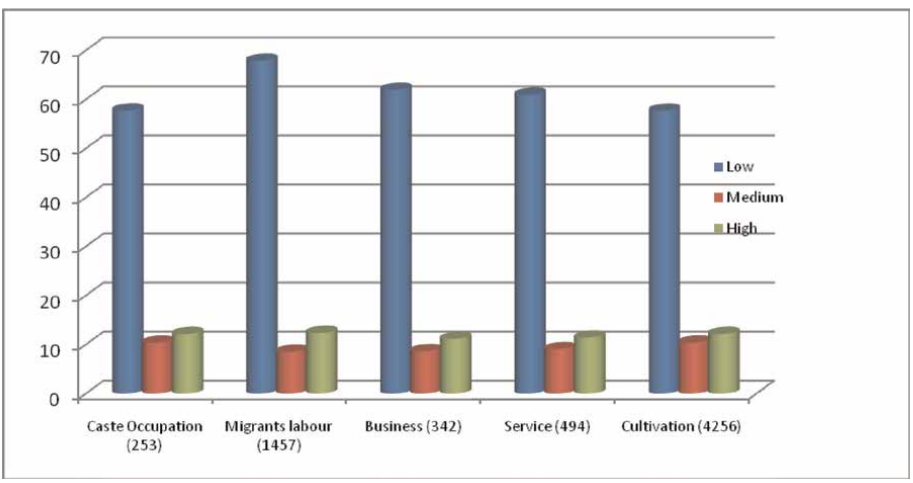

Figure 5.
Knowledge level among the farmers of different occupation (developed by the authors).

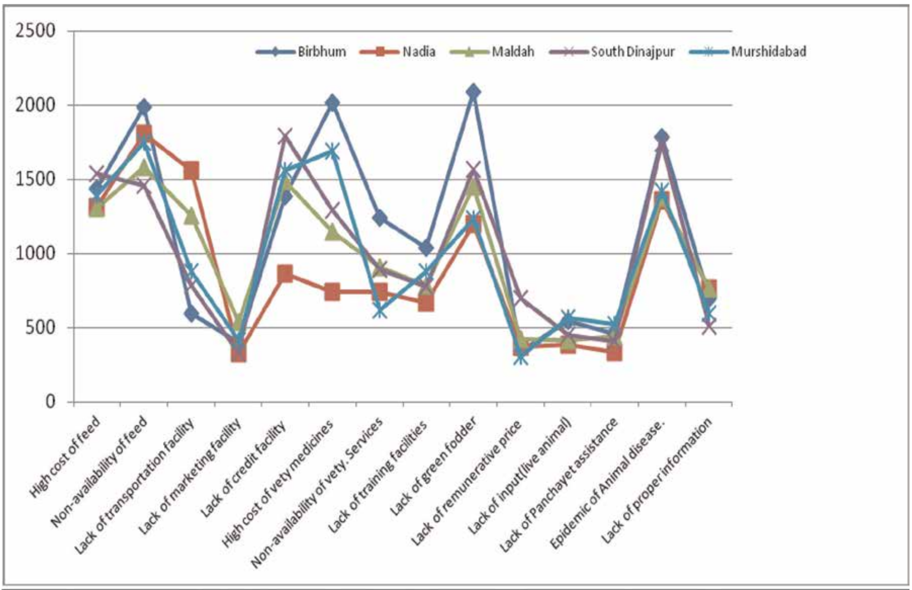

Figure 6.
Constrains among the farmers of aspirational districts of West Bengal (developed by the authors).

relationship with the knowledge level of farmers in five Aspirational Districts in West Bengal (**Figure 6**).

4.5 Constraints perceived by the farmers in aspirational districts of West Bengal

In the aspirational districts of West Bengal, the farmers who raise livestock face a number of challenges, which have been evaluated and are shown in **Table 12**. Overall, constraints show that non-availability of feed (82.22%), epidemic of animal diseases (73.54%), lack of credit facility (68.28%), lack of green fodder (72.30%), and high cost of feed ingredients (67.89%) were the major constraints, while lack of input (22.68%), lack of Panchayat assistant (20.89%), lack of remunerative price (20.12%), lack of marketing facility (18.60%), lack of training facility (38.83%), and lack of proper information (31.48%) were the minor constraint.

The constraints in the various aspirational districts varied accordingly. In the case of Murshidabad districts, the highest constraints were observed to be the lack of feed availability (89.90%), followed by the high cost of veterinary medicine (85.98%) and a lack of credit facilities (81.94%), while a lack of marketing facilities (18%) and the lack of veterinary services (30%) were found to be less of a constraining factor. However, a similar observation has not been recorded in South Dinajpur. Lack of credit facilities (87.98%) and an animal disease epidemic (84%) were reported to be important obstacles in South Dinajpur, while a lack of green fodder was found to be a big obstacle for farmers in Birbhum district.

It was clear that there was not enough land in Birbhum district to grow fodder, and there were a lot of farmers who needed finance in order to expand their farming operations. For improved livelihood, emphasis may be placed on the production of feed and fodder for animal farming. The study closely resembles an observation made by other study [12] who identified a similar set of constraints among goat farmers in

Factors	Birbhum	Nadia	Maldah	South Dinajpur	Murshidabad	Overall
	%	%	%	%	%	%
1. High cost of feed	57.94	64.02	67.89	80	71.97	67.89
2. Non-availability of feed	80	88.05	81.98	72.02	89.9	82.22
3. Lack of transportation facility	24.02	75.98	66.5	36.67	44.07	48.26
4. Lack of marketing facility	16.08	15.98	28.05	15.95	18.06	18.6
5. Lack of credit facility	55.98	42.01	77.66	87.98	81.94	68.28
6. High cost of veterinary medicines	81.37	35.98	55.96	64.05	85.98	65.2
7. Non-availability of veterinary Services	50	40	47.97	47.98	30.05	43.57
8. Lack of training facilities	41.96	30.06	39.97	37.98	43.94	38.83
9. Lack of green fodder	84.02	57.99	76.02	76.79	64.02	72.3
10. Lack of remunerative price	13.73	18.11	21.45	32.62	15.91	20.12
11. Lack of input (live animal)	22.06	20	26.02	22.14	23.61	22.68
12. Lack of Panchayet assistance	18.53	16.33	25.25	20	25.38	20.89
13. Epidemic of animal disease	71.96	66.04	71.95	84.05	73.99	73.54
14. Lack of proper information	28.04	36.45	39.21	24.17	30.68	31.48

Table 12.
Constraints among the farmers of aspirational districts of West Bengal (N = 5000).

six different agro-climatic zones in West Bengal. Since lack of quality input, lack of marketing facilities were considered to be an area-specific constraints faced by the goat farmers under their studies which is not to be a problem in West Bengal.

5. Conclusions

In conclusions, the livestock rearing is a significant contributor in rural economy and plays vital role to raise socio-economic status of the rural people. According to the observations, the majority of livestock farmers in aspirational districts are from the most active age group, have less education, and are of lower socio-economic level. The majority of them live in mixed dwellings and have up to one hectare of land. For most farmers to maintain their security of livelihood, cultivation was their primary occupation. According to the findings, most farmers were married and involved in livestock rearing.

It had been observed that education, training received, occupation and landholding had highly significant effect on adoption index. It had been appeared that adoption index among the farmers of South Dinajpur district was significantly higher than the other four districts namely Maldah, Murshidabad, Birbhum, and Nadia. The result indicated that the farmers of South Dinajpur district were more adapted to improved animal husbandry and fishery practices. It had been observed that majority of the farmers of Birbhum district had low adoption level in comparison to other four districts.

Hence, a comprehensive human resource development (HRD) programme should be conducted for better livelihood generation. Adoption index among the farmers needs to be assessed for sustainable livelihood driven work plan as promising endeavour in future. Considering this scenario, a suitable plan needs to be promoted for better livelihood of the farmers in various aspirational districts of West Bengal with a linkage of available science and technology. In future, a comprehensive farmers' training and demonstration programmes are needed to be conducted in this area for livelihood improvement of the farmers. The adoption level of the farmers about livestock farming needs to be assessed for formulation of proper policies to enhance sustainable livelihood in these districts of West Bengal.

The study on knowledge index of farmers in various aspirational districts of West Bengal explore that, improved technology for scientific livestock rearing is essential for economic gain of stakeholders and farmers. Results of the study revealed that knowledge score among the farmers of Nadia district was highest and in South Dinajpur was lowest than the other three districts namely Birbhum, Maldah, and Murshidabad. Study also revealed that the farmers of Nadia district were having more knowledge about improved animal husbandry practices. Therefore, special attention must be given before implementing any livestock-related entrepreneurial programme among them.

Finally, it also depicted various constraints like lack of training facilities and education, etc. These were the major drawbacks for the upliftment of the socio-economic status of the farmers in the selected districts of West Bengal. It is clear from the findings of the study that farmers use livestock as a secondary job to supplement their income. Therefore, it is observed that small ruminants play an essential role in generating jobs, revenue, capital, and assets. It is crucial to adopt advanced technology and to provide the facilities required for better practices in order to increase the breed's capacity for production.

The rural poor can use livestock raising as an alternative source of income and as a significant way to meet their financial needs. In order to improve the socio-economic situation of these districts, the Government should take steps to provide appropriate training and assistance, and region-specific policies should be created to support this livelihood sector.

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