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ADVANCES
An International Journal for Scientific Research
www.sjournals.com
An official journal of Europub Publishing Company, Ltd. UK

Pure and Applied Science Advances (2025) 13(1) 1-28
ISSN
doi: 10.14196/pasa.v13i1.1835


Contents lists available at Sjournals

**Pure and Appiled Science Advances**

Journal homepage: www.sjournals.com

**Review article**

# The role of feed resources in optimizing reproductive efficiency in goats and sheep

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A R T I C L E I N F O

*Article history,*
Received 21 December 2024
Accepted 30 December 2024
Available online 07 January 2025
iThenticate screening 23 December 2024
English editing 28 December 2024
Quality control 05 January 2025

*Keywords,*
Feed resources
Reproductive efficiency
Nutrition
Goats
Sheep

A B S T R A C T

Reproductive performance in sheep and goats is significantly influenced by the type of food and nutrition consumed. Dietary environment significantly impacts sheep and goat reproductive processes, ranging from minor adjustments in ovulation frequency on suboptimal diets to complete shutdown in adverse nutritional indicators due to adverse nutritional environment. The study explores the influence of different feed resources (traditional and non-traditional) on reproductive performance in goats and sheep, emphasizing the need to understand this to optimize productivity and prevent nutrient deficiencies that can negatively impact reproductive hormones, fertility, and fetal development. Nutrition plays a crucial role in reproductive functions, particularly in small ruminant production, with inadequate nutrition negatively impacting reproduction, especially in females. Grazing is the primary source of nutrition for these animals, and the quality of grazing directly affects their reproductive capacity. Nutritional imbalance can alter reproductive outcomes and pose a life-threatening threat to both mother and offspring. The type, quantity, and composition of feed resources fed to sheep and goats can influence reproduction, particularly during the breeding season. Seasonal feed shortages and poor fodder quality can hinder the reproductive success of grazing animals. Focus feeding strategy focuses on understanding the physiological mechanisms affecting reproduction in female small ruminants to improve their reproductive performance. To maintain sustainable production, the discussion provides direction in selecting suitable feed resources, feeding practices, and reproductive and nutritional scope. Feed resources can be classified into classical and non-classical types, with classical feed resources traditionally used in the commercial sector. To ensure optimal reproductive outcomes, sufficient nutrition and high-quality feed resources are essential. The study offers valuable insights into the intricate connections between feed resources and reproductive performance in goats and sheep, guiding strategies for enhancing fertility and productivity.



**1. Introduction**

In small ruminant farming, reproductive efficiency and nutrition are closely linked, with inadequate nutrition negatively impacting reproduction, particularly in females (Wang et al., 2023; Purushotam Joshi, 2022; Eskildsen et al., 2020). Therefore, providing a balanced diet can help improve the fertility of sheep and goats. Since grazing is the primary source of nutrition for these animals, the body condition of the flock directly influences its reproductive capacity. Nutritional conditions play a significant role in modulating reproduction in sheep and goats because reproductive activities require both the quality and quantity of nutrients (Blache et al., 2008). Efficiently exploiting total feed resources, including forages, agro-industrial by-products, and nonconventional feed resources, can enhance reproductive performance per animal and production per unit of land (Jimma et al., 2016). The use of concentrates as sheep and goat feed may not always result in improved reproductive success. Non-traditional feed options can be more sustainable in low-input systems, reducing costs while maintaining reproductive function (Ben Salem and Nefzaoui, 2004).

Nutrition, either directly or indirectly, influence the folliculogenesis process in the hypothalamic-pituitary-ovarian axis (Prasad et al., 2016). The brain level coordinates reproductive responses to environmental influences, governing the secretion of GnRH (Robinson et al., 2006). However, the impact of nutrition on FSH and LH levels in the blood and GnRH synthesis is unclear and difficult to determine. Digestive products enter circulation and act as signals, regulating GnRH pulse secretion and potentially promoting gamete and hormone production on the gonad. The study by Martin et al. (1984) suggests that the pituitary gland and gonads, central to reproduction control, can respond independently to metabolic inputs, potentially switching the reproductive process on or off, despite the effects of a sudden reduction in feed intake. Poor early pregnancy nutrition may limit the placenta's size, potentially hindering the fetus's normal growth later in pregnancy, even with good nutrition (Lindsay et al., 1993). Nutritional responses can predict ovarian function, embryonic growth, and communication between the embryo and uterus, potentially aiding in early embryonic lethality (Reynolds et al., 2022).

The quality of grazing is crucial for sheep and goat reproduction, with studies indicating that the quantity and feed composition provided to small stock, especially before and during breeding season, significantly influences the reproductive success of does and ewes (Shaukat et al., 2020; Santos et al., 2018). The relationship between diet, LH pulse frequency, and ovulation rate in ewes has been challenging to establish, similar to plasma FSH concentrations (Atkinson et al., 1989). High feed intakes did not affect FSH concentrations but increased LH pulse frequencies during the follicular phase, according to Rhind et al. (1985). In late pregnancy, poor feeding leads to smaller offspring due to inadequate maternal nutrient supply, rather than placental incompetence. Energy and protein are implicated, but glucose appears to play a key role in causing this issue (Robinson, 1977). The capacity for reproduction of semiarid pasture-raised animals may be hindered due to an inadequate diet in the dry season (Kraai et al., 2022). There are two types of feed resources for small livestock: classical feed resources and non-classical feed resources. This review explores the impact of traditional and unconventional feed sources on the reproductive success and failure of goats and sheep.

## 2. Relationships between feed resources and the bio-physiology of nutrition and reproduction in sheep and goats

Understanding the relationship between feed resources and nutrition and reproduction is crucial for reproductive efficiency in sheep and goats (Assan, 2020; Wade and Jones, 2004). The capacity of small ruminants significantly influences reproductive capacity, especially in females (Somchit et al., 2007). Kiyma et al. (2004) reported that inadequate feed supply can negatively impact reproductive performance, depending on the necessary limit and reproductive conditions. Enhancing reproductive performance can be achieved by increasing feed consumption. Tanaka et al. (2004) reported that both short-term and long-term fasting can harm ovarian function in goats, emphasizing the critical role of nutrition in ovarian function and the importance of enhancing success (Rondina et al., 2005). There is a high correlation between the degree of nutrition during breeding and the ewe lamb conception rate. Inadequate nutrient intake levels only affect puberty age when lamb weight is below the minimum BWT of 40 kg needed for healthy puberty onset (Seegers et al., 2011).

Sheep and goat producers have used flushing to improve the reproductive capacities of their animals, as noted by Seegers et al. (2011). This method aims to enhance an animal's physical condition, which directly impacts its fertility. Farmers can effectively influence the reproductive success of their flocks by flushing because the quantity and composition of feed are closely related (Assan, 2022). Feed resources are readily available, and nutritional quality plays a considerable role in ensuring quality reproduction in sheep and goat husbandry. Grasslands and rangelands are the most abundant sources of nutrients for sheep and goats, while bushes, shrubs, and wooded regions are also accessible (Álvarez Ríos et al., 2018). Maintaining high-quality forage in pastures is challenging due to changes in weather patterns and management plans. It is essential to synchronize descriptions of the life cycles of each forage species with the different stages of animal growth (Perotii et al., 2021). The nutritional value of feed resources is related to their capacity to provide specific nutrients.

The nutritional value of feed resources is determined by their ability to provide necessary nutrients for reproduction (Lindsay et al., 1993). This is often dependent on voluntary feed intake, digestibility, the calorie ratio, and the availability of bypass nutrients, particularly proteins (Fisher, 2002). By assessing the forage species that flourish in a pasture, producers can estimate the ideal feed for goats or sheep and the time of year when each forage is accessible. In most instances, focal feeding regimens for small stock are increasingly reliant on improving reproduction while maximizing fodder usage and lowering supplement costs (Assan, 2022).

## 3. The role of protein and energy in sheep and goat reproduction

For sheep and goat reproduction, protein and energy play vital roles by influencing hormones such as oestrogen and progesterone, aiding fetal growth and development during gestation, maintaining uterine health, and supporting normal ovulation and fertility in females (Wang et al., 2023; Purushotam Joshi, 2022; Eskildsen et al., 2020). Reproductive health in does heavily relies on protein, which is crucial for fertility, successful breeding, and healthy pregnancies. Therefore, ensuring sufficient protein intake is critical for maintaining reproductive well-being and preventing related disorders (Khan et al., 2022; Marshall et al., 2022; Rajendran et al., 2022). Protein also plays a significant role in optimal sperm capacitation, conception rate, pregnancy, and reducing abortions in animals (Armstrong et al., 1990). In ewes, protein deficiency can result in low conception, lambing, and twinning rates, while in rams, it can lead to impaired testicular growth and spermatogenesis (Odham et al., 1978).

To enhance productivity under specific conditions and management practices, strategic supplementation is considered the most effective approach (Caton and Dhuyvetter, 1997). During summer, when protein deficiency is anticipated, nutrients should be supplied to address inadequacies or meet production requirements (Robinson et al., 2006). One of the most efficient methods of nutrient supplementation involves using multi-nutrient blocks composed of urea and agro-industrial by-products (Hadjipanayiotu, 1993). The quality of protein has varying effects on fertility and ovulation (Kaim et al., 1983). Incorporating rumen undegradable protein in the diet has been shown to enhance body weight and ovulation rate (Hamra et al., 1992). Higher ovulation rates and improved fertility can be achieved through lupin supplementation during the mating period. Fertility is positively influenced by the addition of undegradable protein and vitamins to urea feed blocks (Marshal et al., 1976). Supplementation may also benefit breeding rams, resulting in improved semen quality and increased sexual activity. The provision of amino acids, which supply nitrogen for ruminal bacteria, makes it difficult to maintain a low dietary protein level (Tan et al., 2021).

Limiting food consumption decelerates metabolic processes (Paula et al., 2020), while insufficient protein can hinder growth, reproduction, and milk production (Eskildsen et al., 2020), as well as weaken the immune system. Conversely, excess protein is eliminated as urea in goat urine, which can be modified to meet nutritional requirements. A diet with 27-30 CP% as a temporary energy and protein source enhanced reproductive efficiency (Melesse et al., 2013). For sheep and goats grazing on rangeland with low protein content, a high-protein diet supplement is advantageous if they are not flushed. However, it can be preserved and utilized prior to breeding (Assan, 2022). Deficits in energy and protein can result in embryo loss, reduced fetal and placental development (Robinson, 2006), and delayed sexual maturation due to decreased hormonal activity in young animals (Dýrmundsson, 1987). Poor nutrition increases the likelihood of pregnancy issues such as miscarriage, stillbirth, and difficult births, while extended low-energy diets disrupt hormone balance, leading to absence of oestrus or silent heat.

Adult females, including goats and sheep, on long-term low-energy diets experience decreased fertility and conception rates due to hormonal imbalances (Redden and Thorne, 2020). Insufficient energy leads to weight reduction, lower body condition scores, and impaired reproductive health. In younger females, low-energy diets can postpone puberty and increase the risk of reproductive tract infections due to compromised immune function (Yıldırır et al., 2020). Prolonged low-energy diets can negatively impact reproductive performance, even after dietary improvements. Proper nutrition is crucial for the well-being and performance of mature females. Imbalanced diets hinder growth and reproductive processes in sheep and goats, resulting in reduced appetite, poor nutrient uptake, weakened immunity, increased disease susceptibility, decreased milk production, and reproductive failures (Maji et al., 2023). It is essential to understand the roles of crucial nutrients in reproduction and the symptoms associated with their deficiencies for maintaining health. Mukusa-Mugerwa and Lahlou (1995) observed that high- and medium-energy diets led to shorter reproductive intervals compared to low-energy diets in Barbari and Jamunapari breeds.

Carbohydrates, fiber, and lipids are vital for ruminant reproduction. Energy sources enhance reproduction, with fat providing energy for rumen bacteria to degrade starch, lipids, and fiber into VFAs for absorption and energy use (Purushotam, 2022).

Flushing reduces abortions in merino ewes, and adequate nutrients increase fetal nutrient supply, resulting in higher birth weights. Rastiogi et al. (2006) reported lower birth weights in kids born to dams with low concentrate supplementation. Most legumes contain estrogen-like compounds affecting cervical health, ovarian function, uterine health, conception rates, and sperm transportation. Singh and Bhakta (2022) showed that supplementing Black Bengal goats with 2-4% concentrated dry matter from 2nd grade Trigonella foenum seeds for 120 days improved growth and reproductive performance without adverse physiological, hematological, or biochemical effects. Aduli et al. (2004) found that feed blocks before and during mating increased conception and twinning rates in sheep, likely due to increased nutrient availability, particularly protein, as the reproductive axis is sensitive to nutrition and metabolic reserves significantly impact reproductive function. High-energy prenatal diets improve oocyte maturation and embryonic survival, even with a post mating control diet (Ashworth et al., 2010). Adequate protein and energy intake, along with monitoring BCS, are recommended for optimal reproductive performance in sheep and goats.

## 4. Modulatory effects of hormones and metabolites on the reproductive function of sheep and goats

Reproduction in sheep and goats is influenced by hormones and metabolites, including gonadotropin, metabolic factors, and sexuality (Bazer, 2020). Dysfunction in the endocrine complex can directly affect fertility (de La Salles et al., 2020). Severe food shortages can lead to decreased adult reproductive performance in sheep due to impaired ovary development (Lindsay and Martin, 1994). Understanding blood metabolites and hormone changes is crucial for reproductive regulation (Ivell and Anand-Ivell, 2021). Nutrition plays a role in enhancing fertility rates by affecting blood levels of urea, protein, and estrogen (Alemany, 2021). H. The endocrine system and nervous system interact vitally for reproductive function, with the hypothalamus, pituitary, and gonads secreting hormones (Siu et al., 2021). Neuroendocrinology is the primary regulator of follicle growth and ovulation, which is subject to nutritional stress.

Reproduction success is determined by multiple hormonal actions, including sex and gonadotropin hormones (Sekiguchi, 2016). Inadequate dietary provisions can impair the reproductive hormone complex. Hormones regulate reproductive activity and nutritional body condition (Zarazaga et al., 2005). However, the connection between metabolic mechanisms and fat storage, food intake, and reproduction systems is not well understood. Figure 1 gives a schematic representation of hypothalamus-pituitary axis in endocrine system. Schneider (2004) reported that metabolic status impacts reproductive function by modulating the GnRH neuronal network at the hypothalamus, primarily through hypothalamic peptidergic systems responsible for energy balance. Metabolic challenges can alter the GnRH, LH, and FSH surge independently of their effects on pulsatile LH secretion (Margues et al., 2024). The hypothalamic-pituitary-ovarian axis regulates the secretion of gonadotropins by developed follicles, which secrete steroid hormones (estradiol and progesterone) and peptide hormones (inhibin, activin, and follistatin). Estradiol and progesterone can have positive or negative feedback, altering pulse frequency and amplitudes at both hypothalamus and pituitary levels (Millar, 2005).

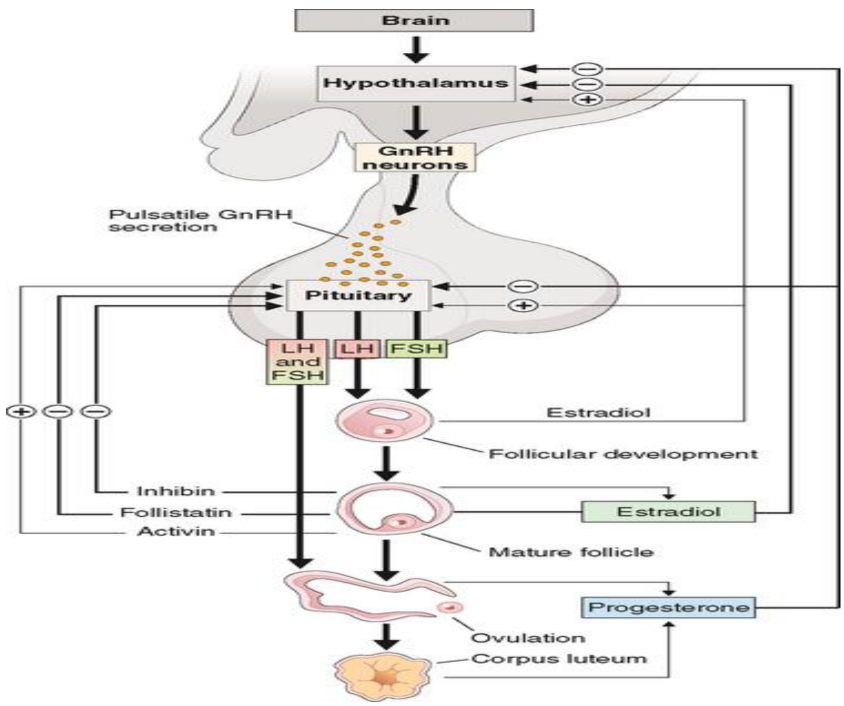


**Fig. 1.** A diagrammatic presentation of the hypothalamic-pituitary-ovarian axis (Gupta and Chia, 2015)

The microenvironment of oocytes and embryos can be influenced by nutrition and internal and external factors, making them unsuitable for fertilization and development (Lassoued et al., 2004). Throughout reproductive and production stages, hormonal and metabolic changes occur, with insulin playing a crucial role in maintaining glucose homeostasis (Sliwowska et al., 2014). Insulin regulates energy balance and neural reproductive control, and its impact on reproductive physiology has been demonstrated in animal models, affecting GnRH/LH production. Insulin may be necessary for reproductive events if it interacts with specialized nerve terminals (Mukherjee et al., 2022).

Nutritional responses can predict ovarian function, embryonic growth, and communication between the embryo and uterus, potentially aiding in early embryonic lethality (Prasad et al., 2016). Nutritional supplements, either directly or indirectly, influence the folliculogenesis process in the hypothalamic-pituitary-ovarian axis (Robinson et al., 2006).

The brain coordinates reproductive responses to environmental influences, governing the secretion of GnRH. However, the impact of nutrition on FSH and LH levels in the blood and GnRH synthesis is unclear and difficult to determine (Millar, 2005). Brain peptides significantly influence the pituitary glands hormone release, which regulates reproduction (Martin et al., 2004). Gonadotropins control ovarian function. Extra nutrition doesn't change ovulation rates, but it may affect hormone release patterns (LiverTox, 2018). Feed flushing, a mechanism used in sheep management, increases the release of gonadotropic hormones, such as LH for oocyte maturation and FSH for increased ovarian production, improving ovulation rates (Kosgey and Okeyo, 2007). Nutritional supplementation may affect the sensitivity of granulosa cells in large follicles to FSH action (Guo et al., 2019).

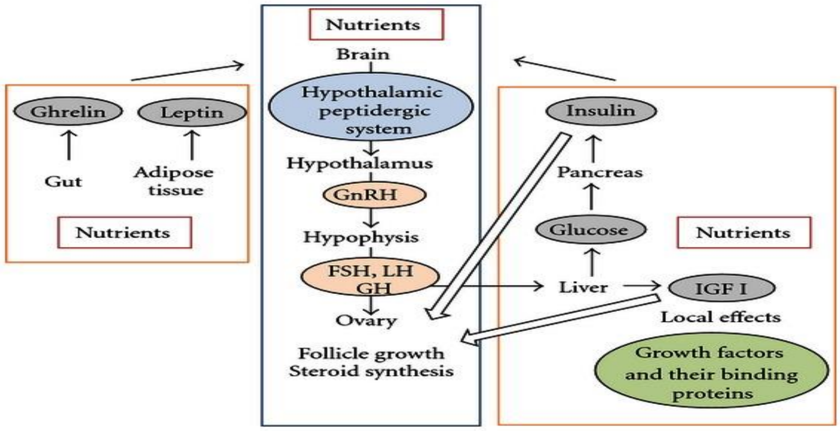


**Fig. 2.** Schematic representation of mechanisms by which nutrition influences reproductive function (Garcia-Garcia, 2012)

The relationship between nutrition and reproductive function in sheep and goats is complex and interdependent (Robinson et al., 2006). Nutrients play a crucial role in hormone production, which impacts reproductive processes like follicular development and ovulation. A well-balanced diet provides essential nutrients, vitamins, and minerals that support reproductive health, while a diet lacking key nutrients can negatively impact fertility (Assan, 2020). The type of food and nutrition consumed significantly influences reproductive performance in these animals (Yıldırır et al., 2022).

## 5. The impact of supplementation and grazing regimes on reproductive efficiency in sheep and goats

The combination of supplementation, grazing, and reproductive management can significantly enhance the reproductive performance of sheep and goats, particularly for female animals such as pregnant ewes or dry mated does (Assan, 2022). The most efficacious supplemental feed is cake, while the most economical option is the byproduct of processing coconut, groundnut, cottonseed, and palm oils (Chisoro et al., 2020a). Farmers can utilize any accessible feed depending on the agro-ecological region (Chisoro et al., 2020a). Banchero et al. (2021) determined that the general expenditure of energy during dietary supplementation had the greatest impact on ovarian activity, with sheep grazed on tanniferous legumes exhibiting higher ovulation rates.

Ovulation rates in non-supplemented ewes were observed to decline when access to legumes rich in polyphenols was provided. However, supplemented sheep ovulated at a higher rate than native pasture ewes, despite consuming less protein. A study by Urrutia-Morales et al. (2012) found that individual animals administered 400 g kg-1 of 14% CP and 292 mcal kg-1 of supplements demonstrated higher pregnancy rates. The results suggest that dietary supplements and male sex may trigger neurophysiological pathways that increase ovarian activity, creating an environment conducive to fetal implantation during the anestrus season. The increased abortion rates observed in rangeland-based marginal goats were noted regardless of the dietary regime employed during the prenatal period.

Inadequate dietary intake during the third month of gestation is critical for reproductive processes in grazing lambs and sheep. Studies indicate that ewes supplemented with nutrients experience fewer barren pregnancies and higher twinning and lambing rates in arid regions (Dyrmundsson, 1981) and Al-haboby et al. 1999). The primary source of nutrition for sheep is grazing stubble; however, as the season progresses, the supply of nutritious components diminishes. Berhanu et al. (2013) found that animals fed concentrate mixtures can achieve conception rates up to 29% higher than grazing-only groups. Feed blocks supplementing ewes before and during mating can also enhance conception rates and twinning percentages.

The utilization of blocks as supplements in livestock increased the quantity of nutrients, particularly proteins (Chisoro et al., 2020b). Flushing options include providing animals with nutrient-rich grass and high-energy supplements. Fresh pasture or supplementation with 10% to 12% crude protein grains per head per day can both result in flushing. Pre-ovulatory lupin grain supplementation during the final 10 days before mating improved ovulation rates. Flushing with grazing grass or supplementation with high energy can increase profitability.

The study by Karikari and Blasu (2009) identified a correlation between nutrition and the age of West African dwarf goats. The average litter size in dams aged 2-3 years was 213, while older dams had an average litter size of 150. Young females benefited more from supplementation than older dams. Adeoye (1985) and Webb and Mamabolo (2004) reported similar patterns in indigenous goats, reaching optimum fertility at ages 3 and 4. Goat production can enhance profitability through flushing grazing grass and providing additional feeding during wet weather.

## 6. The influence of classical feed resources and dietary accessories on reproduction in sheep and goats

Classical feed resources and dietary accessories significantly impact sheep and goat reproduction due to their nutrient supply and hormone regulation (Yıldırır et al., 2022; Jimma et al., 2016). Major feed resources include natural pasture grazing, hay, green feeds, and concentrates like nog cake, cotton seed cake, grains, molasses, wheat bran, commercial concentrate mix, and brewery grain waste (Yoseph, 1999; Yosef et al., 2003; Nigussie, 2006; Adugna, 2008; Mureda and Zeleke, 2008; Sintayehu et al., 2008; Yitaye et al., 2008). The dietary composition of legumes and grasses also impacts reproductive well-being. Legumes are high in calories, while lambs and sheep prefer grass (Wei et al., 2022). Lambs and sheep mix legumes and broadleaf plants, while goats prefer grass (Redden and Thorne, 2020). Protein is abundant in legumes, while sheep prefer an assortment of both (Affrifah et al., 2023).

### 6.1. Lucerne (Medicago sativa) or alfalfa and reproduction in sheep and goats

Alfalfa, also known as Lucerne, is a perennial legume plant used in animal agriculture for grazing, hay, silage, green manure, and cover crops (Ghaleb et al., 2021). It provides essential nutrients like protein, vitamins, and minerals to goats and sheep. A study by Al-Geldawy et al. (2014) tested three rations of Alfalfa, including an 82% concentrate feed mixture, 50% CFM, 30% fresh alfalfa, and 20% maize grains. The results showed significant variations in conception and lambing rates for ewes, with conception rates being 36.4 and lambing rates being 18.2%, respectively.

Alfalfa contains phytoestrogens that may reduce domestic ruminant reproductive efficiency, but it remains beneficial for twinning, weaning, and ewe efficiency (Bennett's, 1946; Lightfoot and Worth, 1974). It should not exceed 30% of total nutrient requirements on a DM basis. Alfalfa contains saponin, which can be toxic to goats and sheep if consumed in large quantities. However, it is easily digestible and beneficial for both species (Kara et al., 2010), Kochapakdee et al. (1994), and Robinson et al. (2001). Proper feeding of ewes using pelleted complete diets, especially during late gestation, is crucial to prevent lower birth weights and higher mortality rates in pregnant ewes (Martin et al., 2004).

Cranston et al. (2015) found that lucerne consumption before mating can reduce the number of eggs shed per oestrus and the proportion of fertilized eggs by 20%. Lucerne and clover have been used to increase lamb growth rates, ewe milk production, and early weaning. Adams (1995) suggested that lucerne hay contains fewer oestrogenic hormones and has no effect on fertility. Liu et al. (2001) suggested that the leaves of Leucaena leucocephala, Morus alba, and Azadirachta indica can be potential nitrogen supplements. Lowry (1990) suggested that farmers feed combinations of various leaves to livestock, which dilutes issues of palatability and toxic consequences. Coumestan, a phytoestrogen found in lucerne, can impair reproductive performance when concentrations exceed 100 ppm.

Studies have shown that fresh leaves combined with Gliricidia sepium-L. or Leucocephala calliandra calothyrsus, or a mixture of L. leucocephala-M. and alba-Tectona grandis leaf meal (LMAM) can be used as strategic supplements in cow and goat diets (Anbarasu et al., 2001). Grazing ryegrass pastures for three weeks before breeding can counteract phytoestrogen effects. However, lucerne feeding on ewe lambs has been compared to pasture due to the negative effects of coumestan. It is generally recommended not to feed lucerne prior to breeding (McGaveston, 2012).

Robertson et al. (2015) and Taylor et al. (2002) conducted studies on the impact of lucerne on ewe lamb breeding, pregnancy, and reproductive rates. They found that lambs given lucerne had a higher percentage of twin fetuses than those given unimproved ryegrass pastures. However, limited data is available on the effect of feeding lucerne to ewe lambs during breeding. The present study revealed that providing lucerne before breeding had no detrimental effect on the number of fetuses detected. Taylor et al. (2002) reported poor body scores, low lambing rates, and poor wool characteristics in ewes without adequate feed supplements during gestation. Legumes, such as alfalfa, have a high CP and low energy content, which could affect the effects of lucerne on ewe lambs (Abdel-Malik et al., 2001; Turner et al., 2011).

Abdelrahman et al. (2017a) highlighted the importance of maternal nutrition in foetal growth and development, particularly during late gestation. Strategic energy supplementation is used to improve small ruminant performance, while alfalfa, a high protein source, is recommended for goats and sheep at a daily feeding rate of 2-4% of their body weight (Gonzalez et al., 2001; Broderick, 2006). Alfalfa is high in protein, carbohydrates, and minerals, and is commonly produced in pellets and cubes (Turner et al., 2011). These findings highlight the nutritional value of alfalfa in livestock growth, production, and reproduction (Pozdiek and Vaculova, 2008).

**Fig. 3.** Lucerne establishment

### 6.2. Red clover (*Trifolium pratense* L.) and reproduction in sheep and goats

The red clover (Figure 4) a perennial legume forage primarily found in temperate regions, is a short-lived perennial that typically lasts 2-4 years (Adams, 1998). Red clover, a forage legume, is rich in isoflavones, which are chemically similar to endogenous oestrogens, providing physiological, particularly oestrogenic activity (Adams, 1995). The estrogenic activity of subterranean clover was first observed in the 1940s when Australian sheep were affected by the "clover disease" (Bennets et al., 1946; Kingsbury, 1964). The study by Davies and Hill (1989) and Davies et al. (1970) found that the formononetin content in subterranean clover cultivars can affect sheep reproduction, leading to increased teat and gestation length, uterine weight, and prolapsed vagina and cervix (Cox and Braden, 1974, Trenkle and Borroughs, 1978).

Adams (1990) reported ewes had permanently damaged reproductive tracts due to oestrogenic pasture grazing, despite the absence of classical clinical "clover disease." Furthermore, exposure to non-oestrogenic pasture results in reduced fertilization rates in clover-infertile ewes due to inability to store spermatozoa in the cervix and reduced spinnbarkeit in cervical mucus due to slower oestrogenic stimulation. Mustonen et al. (2014) examined the impact of red clover silage with high phytoestrogen content on ewe performance during the first breeding season. They fed Finnish Landrace ewes red clover silage containing formononetin, biochanin A, genistein, and daidzein, while the control group received grass silage. The main difference was in fetal fluid content. Thomson (1975) examined forage diets from ryegrass and red clover, with the control grass diet showing a higher twinning rate than red-clover diets. The lambing percentages were 190,165, and 100% for all treatments. The study recommends avoiding grazing red clover and feeding it before and during mating in flock management. Sarelli et al. (2003) found that the phytoestrogen content in red clover raw material and silage varies based on plant growth stage and wilting.

**Fig. 4.** Red clover growing in pasture

### 6.3. Lupins and reproduction in sheep and goats

Lupinus (Figure 5), commonly known as lupin, lupine, or regionally bluebonnet, is a genus of plants in the legume family Fabaceae (Drummond, 2008). Lupins are a safe and nutritious feed for sheep, providing protein and energy (Kenney and Roberts, 1987). They are effective in reproduction and drought-feeding situations. The study found that ewes fed 400 g/day lupin grain during mating on dry pasture produced 24% more lambs per year, due to more twins being born, compared to ewes fed lupin stubble. During the dry period, farmers often feed supplements to either boost growth rates or reproductive performance of their livestock (Sweetingham and Kingwell, 2008).

Using lupin grain as a source of extra energy and protein, Somchit et al. (2007) investigated the effects on follicle development and the levels of other metabolites. Although it was anticipated that supplementation would increase follicle counts, progesterone levels in peripheral circulation actually decreased after lupin supplementation, although this improvement was not statistically significant. These results supported the notion that nutrient-specific ovarian activities can regulate dietary influences on folliculogenesis; however, Banchero et al. (2012) discovered that not all legumes had the same effects.

Although legumes with little or no endogenous tannins provided the same amount of protein and energy, this was not the case despite ewes fed tannin-rich legumes having a higher ovulation rate than control ewes. The findings of Vinoles et al. (2009), King et al. (2010), and Robertson et al. (2015) support the conclusion that feeding legumes for 12 or fewer days can increase the ovulation rate. A response in ovulation rate required 3 weeks of grazing or supplementation with silage made from high-quality pastures.

Vinoles et al. (2009) reported an increase in the number of lambs born after 12 days of grazing pasture prior to mating in a comparable trial. The shortening of the feeding period of lupin lowered the chances of embryo mortality due to insufficient nutrition while also reducing the amount of feed delivered.

Although the total follicle count did not differ significantly, researchers in 1989 discovered that ewes fed lupin grain had more total follicles even though progesterone levels were lower. Lupin supplementation increased glucose levels. Based on these findings, it appears that localized ovarian responses are influenced by feeding and that diet influences follicular growth. This demonstrates that the energy-generating components of lupins induce follicle activity at a more noteworthy pace than in sheep, which is caused by metabolic cycles in addition to glucose generation and acetic acid derivation ingestion.

**Fig. 5.** Native Blue Lupine plant

Fletcher (1974) demonstrated that dietary stress leads to decreased ovulation rates in Merino sheep. The increase in embryo death may have been caused by the decrease in progesterone that occurred following the administration of the lupin grain. Canola meal-fed ewes gained slightly more weight than lupin-fed ewes. Canola meal is a viable option for commercial sheep producers because it is less expensive than other sources of comparable proteins and is partially protected from rumen degradation. To produce sufficient protein in terms of energy or amino acid composition to meet nutritional requirements, it is absolutely necessary to feed late-pregnancy proteins to ewes that do not undergo rumen degradation during the latter stages of pregnancy. The increase in birth weight observed in ewes fed lupin may be explained by this difference.

Increased protein intake has occasionally been linked to an increase in sheep birth weight and growth rate. As a result, a high-protein supplement during specific stages of pregnancy may help a lamb grow and grow larger at birth. Most protein sources used as supplements for grazing sheep (e.g., grain legumes) are highly degraded in the rumen (>0.8 fermented in the rumen) and contain low concentrations of SAA). Proteins that are more resistant to degradation in the rumen, such as fishmeal and meat meal, may be more expensive and have lower palatability.

### 6.4. Wheat and its by-products and reproduction in sheep and goats

Trach (2000), Animut et al. (2002) and Habib (2008) have all contributed to the understanding of the potential benefits of chemical treatment of wheat straw for sheep and goats. They found that the treatment of wheat straw with urea and lime enhances its nutritive value and is economically feasible (Trach, 2000). However, the effects of these treatments on animal performance are often variable, and the efficiency to digest poor-quality roughages also depends on the animal species and breed (Habib, 2008).

Nianogo et al. (1999) and El-Meccawi et al. (2009) found that higher dry matter intake (DMI) for treated straws may increase fibre digestion in the rumen. The intake is comparable to 42 g per kg BW0.75 previously recorded in goats fed sorghum straw treated with 2% urea solution or wheat straw as a sole diet. Oat straw is the most palatable and nutritious, followed by barley straw and wheat straw. Millet straw is more palatable and higher in energy and protein, while flax straw has lower feed value due to lower digestibility (Smart et al., 2021).

Despite the fact that it has a moderately low rough protein content and metabolizable energy yield, grain straw accounts for a large part of the development of downpour in winter oats and is often the main feed accessible to sheep and goats (El-Meccawi et al., 2008). To determine their metabolizable energy intake and heat production, the same author calculated the energy and nitrogen balances of desert-adapted fat-tailed Awassi sheep and mixed-breed goats when they were only given ad libitum access to wheat straw. It was predicted that goats would be better able to use wheat straw as a source of energy and nitrogen than sheep because it was hypothesized that sheep and goats have different abilities to use wheat straw (Martin et al., 2005). For ruminants such as goats and sheep, straw is a convenient, practical, and reasonably priced source of food. To store feed for livestock during lean months or when high-quality roughage is difficult, producers frequently collect and stack straw from their farms.

Patra et al. (2006) discovered that supplementing wheat straw with a leaf meal mixture (LMAM) of Leucaenaleucocephala, *Morus alba*, and Azadirachtaindica or a commercial-type concentrate containing SBM prior to mating and late gestation increased nutrient utilization in indigenous nondescript goats. Guerrero-Cervantesa et al. (2016) studied the effects of substituting hydroponically grown whole plant green wheat (Triticumaestivum L.) for dietary dry-rolled corn grain (DRC) and cottonseed meal (CSM) on reproductive parameters and blood metabolites in Katahdine ewes during mating and gestation. Finally, hydroponically grown green wheat could replace a portion of the DRC and CSM in the diet of ewes during gestation with no negative consequences. In this case, the gestation diet consisted of 70% oat hay, 20% rolled maize grain, and 10% cottonseed meal. In this study, there was no effect of diet on reproductive indices by substituting hydroponic green wheat (HGW) for DRC and CSM on dry matter intake during gestation. During pregnancy, diet had no effect on plasma insulin, cortisol, or progesterone levels.

Patra et al. (2003) found that M. sativa feeding led to a positive energy balance, while S. saligna feeding resulted in a negative energy balance. This suggests that reproduction in small ruminants may suffer as a result of a negative energy balance. The females were fed either a concentrate based on SBM or a leucaenaleucocephala, Morusalba, or Azadirachtaindica (2011) (LMAM) prior to conception and during gestation. a leaf meal mixture (LMAM) may contribute up to 36% of the total DMI in gravids without affecting their overall health or reproductive efficiency, and dams appear to perform similarly when supplemented with wheat straw or a commercial type of concentrate containing soybean meal (SBM).

### 6.5. Soybeans and their by-products and reproduction in sheep and goats

Soybean is among the most essential components of animal feed in the world; each year, millions of tons are produced, and depending on how well the dehulling process is performed, many hulls are the main byproducts of the soy industry. Depending on the variety and seed size, soybean hulls can contain differing amounts of cellulose. 2951 hemicelluloses, 1025 lignin, 1-4 pectins, 48 proteins, and 1115 minor extractives on a dry weight basis, the soybean hull is also known as the seed coat. Hulls compensate for approximately 8% of the total seed, and their proportion traditionally decreases with seed weight.

The moisture content of the soya hull is 7-8%, while proteins and lipids constitute 9% and 43%, respectively, of the highly digestible fibrous feed obtained as a byproduct after processing. The byproducts of ruminants can be excellent sources of nutrients. Its intriguing coproduct is similar to that of forages in that it has more fibre than starch. As is typically the case with coproduct additives, compounds have distinctive nutrient profiles as well as physical characteristics that demand attention when constructing diets. They frequently have multiple nutritional purposes, including forage energy and protein.

The main benefits of coproduct feeds for sheep and goat farmers are lower costs, better animal performance, and less labor-intensive harvesting. The best results were obtained with 9 soybean hulls, and it is more likely that 12 soybean hull supplements provided too much protein given that soybean hulls are high in protein that is degraded in the rumen (excess protein, regardless of protein source or degradability, has been associated with a range of reproductive dysfunctions).

Kid birth rates were much lower when soybean supplements per doe were combined with feeding on natural grasslands than when natural pasture grazing occurred on its own. This research demonstrated that supplementation with a small amount of full-fat soy can reduce the negative effects of maternal and fetal malnutrition during key developmental periods. Livestock may receive the feed they need by being fed soy. Feeding up to 2% of one's body weight in soy waste has no negative effect on fecundity. Rahman et al. (2015) concluded that soya waste supplementation is an inexpensive substitute for pricey compound feed and that the weight increase or reproductive efficiency of limited foods such as grass goat feed intake are unaffected by soya waste concentrations.

### 6.6. Cotton and its by-products and reproduction in sheep and goats

Fasanya et al. (1992) reported that dams given cottonseed cake (CSC), a protein supplement, reached adolescence 190 days earlier and were 10 kg heavier than those given only maize for 240 days (10 kg), only maize for 260 days (9 kg), or no supplementation for 219 days (10 kg). While feed consumption was high across the groups, the mean body weight increase at first standing oestrus was not. It was discovered that CSCS supplementation in the diet can influence the onset of puberty in these females depending on their age and body weight changes when they reach puberty. Cottonseed cake contributes 46% of CP; the greater the undigestible protein levels in the rumen are, the greater the RUDP in the CSC and cotton grain meal (Wadhwa et al., 1993).

Gossypol affects animal reproduction in a variety of ways, including decreasing sperm quality, disrupting the estrous cycle, and disrupting early embryonic development. This compound is one of numerous polyphenolic chemicals found in cottonseed pigment glands (Gadelha et al., 2011). Derivatives are governed by the level of oil extraction in addition to further processing to reduce their concentration to favourable levels for use in feed (Wadhwa and Bakshi, 2016).

Cotton seed glands produce gossypol, which is found in roots, leaves, and stems. Meals contain a large number of conjugated amino acids, and the free form of industrially extracted gossypol is produced from uncooked cotton seed meal oil. Antinutritional factors are thought to be physiologically inert, yet some binding ruminants are able to absorb and digest it. Gossypol, linked to amino acids, is supposed to be indigestible, but ruminants may consume and absorb some fibre.

## 7. Non-classical (non-conventional) feed resources and their dietary accessories influencing reproduction in sheep and goats

Non-conventional feed resources (NCFR) are feeds that livestock farmers and feed producers often do not incorporate into their commercial feeds for animal feeding (Chadhokar, 1984). NCFRs, which are non-food by-products, are often less valuable than their collection and use costs, leading to their discharge as waste and some contain harmful anti-nutritional components (FAO, 1985). The use of non-classical feed resources and dietary accessories should be thoroughly assessed for safety, efficacy, and potential interactions with other nutrients on their impact on reproduction. According to Chadhokar (1984), non-traditional feed supplies comprise of sugarcane meal, rubber seeds, water plants, bagasse, cassava vegetative component, and palm leaf and palm-processed fiber. Nontraditional feed supplies are characterized as shrub fodder, tree fodder, and agro-industrial byproducts that have never previously or economically been used to feed livestock. Amata (2014) reported that unconventional feed sources are being used due to the scarcity of feed.

Chisoro et al. (2020) reported that the nonconventional feed resource (NCFR) category is becoming increasingly populated with feed resources, which typically consist of a diverse range of feeds derived from nonagricultural plants along with feeds derived from other agroindustrial products. Substitute feed sources for animal feed have emerged as a solution to the problems that arise as a result of feed supply limitations and low feed quality. Boufennara et al. (2012) reported that many of these feed sources are deficient in nutrients and energy but also contain high levels of antinutritional elements. Ben Salem et al. (2004) reported that small ruminant feed is the costliest activity in a sheep and goat enterprise; therefore, there is a need to understand the principles of sheep and goat feeding for the purpose of increasing output. Conventional feeds are occasionally unavailable or prohibitively expensive, necessitating the use of alternate feed sources (Chisoro et al., 2020b). They state, however, that the choice of alternative feed resources is determined by the agroecological region,

### 7.1. Halophytic forage shrubs and reproduction in sheep and goats

Halophytes (Figure 6) are a group of various species of trees, shrubs, forbs, and grasses that are not a distinct taxonomic group (Attia-Ismail, 2018). They can grow naturally or be planted, with their biomass production and quality varying significantly from season to season and area to area, primarily due to environmental factors (Squires and Ayoub, 1994). Environmental conditions significantly influence the quantity and quality of nutrients produced by halophytes, with decreased protein levels under salinity attributed to low nitrate ion uptake and other factors (Agastian et al., 2000). The energy content of halophytes is typically estimated in vitro, which may be unrealistic and not represent real in vivo values (Attia-Ismail, 2015). However, these in vitro values relate to some extent to the in vivo ones (Masters, 2006).

Palatability in forage populations of a given species varies greatly between plants, indicating varying levels of plant diversity. Forage quality is influenced by factors such as palatability, nutrient content, plant secondary metabolites, feeding value, voluntary animal intake, and ultimately, animal performance (Attia-Ismail, 2008). All halophyte forage species have sufficient major and minor minerals to meet ruminant requirements, except for phosphorus and sulfur (Kearl, 1982).

Feeding halophytic forage shrubs such as Acacia saligna, Atriplexhalimus, and Cassava manihotesculenta in place of Berseem hay (hay) in Barki ewes' diets has been shown to have positive effects on reproductive activity, physiological response, and some blood biochemical parameters, according to EL-Gohary et al. (2017). Feeding halophytic forage shrubs had no negative effect on progesterone hormone concentrations and thus had no effect on Barki ewe reproductive efficiency. Furthermore, the number of services provided per conception did not differ significantly between the experimental groups, indicating that feeding these ewes halophytic forage shrubs did not reduce the conception rate. Progesterone levels in blood plasma did not differ significantly between the experimental groups except at 16 and 30 days after mating. Feeding halophytic shrubs did not negatively affect progesterone hormone concentrations and therefore did not impair the reproductive efficiency of Barki ewes.

**Fig. 6.** Halophytic forage shrubs

In an EL-Gohary et al. (2017) study with bark ewes fed halophytic forage shrubs, ewes had fewer days open than did the other experimental groups, while ewes fed cassava had the greatest percentage of normal estrous cycle duration (25-40 hrs.), representing 70% of the total number of oestroid cycles in ewes. Fecundity and prolificacy (litter size) were highest in sheep-fed cassava (1.22). T3 hormone activity, AST, and blood plasma Zn, Mn, and Cu concentrations differed between the experimental groups. Eventually, feeding halophytic fodder plants to Barki sheep caused no serious physiological problems or reduced their reproductive potential. Straw, hay, or dry grass-as little as 20 grams of green leaves per day-can help with digestion. Protein can be obtained from halophytic plants.

Halophytic forage plants are less appealing because they contain salts, tannins, and other undesirable components (Attia Ismail, 2015). These antinutritional substances also have an effect on the digestion and nutritional value of forages. As a result, substituting traditional roughages such as hay and straw with halophytic forage bushes or combining them with other feedstuffs is a viable option, and the animals will not require any additional inducement to consume these forages. Estrus duration and activity are the main criteria for estrous behavior (Shetaewi et al., 2001). The salt-tolerant plants had a normal conception rate and did not differ significantly from the control plants, which is consistent with their findings.

### 7.2. Spineless cactus and reproduction in sheep and goats

Spineless cactus (Figure 7) are a type of adaptable feed vegetation that may be consumed by animals. Cacti are rich in carbohydrates, macrominerals, and vitamins but poor in crude protein and fibre; they are often utilized as water supplies for animals bred in harsh environments (Amata and Nwagu, 2012). Rosales-Nieto et al. (2021) reported that regardless of protein fortification, feeding Cacticus improved reproduction without increasing body weight. Sakly (2014) enhanced prolificacy indices in fat-tailed Barbarine sheep by using sheep cactus. Rekik et al. (2012) investigated the effects of Caticus on ovulatory reactions in sheep. Sheep were divided into equal groups and fed either concentrated feed or Cactus cladodes. The proportion of ovulatory eggs increased in both groups during the ram effect-induced ovulatory cycle. At oestrus, ewes fed cactus had 1.6 large follicles, whereas those fed concentrated cactus had 1.4 large follicles.

**Fig. 7.** Spineless Cactus (*Opuntia varieties*)

**7.3. Prosopisjuliflora pods (PJP) and reproduction in sheep and goats**

Prosopisjuliflora pods (Figure 8), an unusual feed, may be economically advantageous for lowering feeding costs and can be a significant factor for feeding sheep and goats using different management techniques (Obeidat and Shdaifat 2013). The concentrate mixture reduced weight gain by up to 50% in sheep, without affecting feed intake. The protein-rich seeds in pods require grinding or milling for livestock to reach their full nutritional value. The raising of animals in dry areas around the world depends on the use of alternative feed sources that are adapted to long dry seasons (Gusha et al., 2015).

Sirohi et al. (2017) examined the effects of feeding crushed and whole dried PJP on the feed intake of goats living in dry climates; all of the goats displayed signs of heat. Buzio et al. (1972) found no difference in reproductive effectiveness between goats fed different PJP-supplemented meal types. The study also found no negative effects on chewing, growth performance, or reproduction elsewhere when sheep and goats were fed PJP at age 60. However, reports comparing the rate of reproduction in goats fed different PJP-supplemented meal types are scarce.


**Fig. 8.** Prosopis Juliflora Pods

**7.4. Tanniferous trees and shrubs and reproduction in sheep and goats**

The list of tannificous trees and shrubs includes Acacia, Quercus, Terminalia, Eucalyptus, and Leucaena species (Britannica, 2024). Tannins in tanninferous trees and shrubs can affect sheep and goat reproduction by reducing fertility, disrupting hormone balance, reducing sperm quality, and increasing abortion risk (Besharati, 2022). High tannin intake can decrease fertility in both males and females, disrupt hormone levels, and decrease sperm motility and viability (Molino, 2023).

Acacia species (Figure 9) are commonly used as fodder bushes for goats (Amira et al., 2014). Africa is home to a wide range of Acacia species (Mlambo et al., 2008). Acacia leaves can be used to supplement protein and energy in animals fed low-quality roughage (Krebs et al., 2007). However, the main issue with using Acacia bushes in animal feed is that they contain antinutrients. The effects of tannins on protein digestion and feed intake have been studied, and recently, there has been a focus on the antioxidant effects of tannins on male fertility. Leguminous seeds and pods, shrubs, and novel pasture species are affordable, abundantly available, and excellent for grazing sheep and goats in semiarid environments (Vasta et al., 2008).

Secondary chemicals such as tannins are also found in these plants. Non-conventional feed resources contain secondary chemicals like tannins, which can be harmful to animals due to excessive dietary condensed tannins or protein concentrations. In tropical conditions, these compounds can be anti-nutritional (Das et al., 2020). In trials involving ruminant animals, the benefits of these compounds were only partially proven, such as in sheep, goats, and cattle (Mueller-Harvey, 2006).

**Fig. 9.** Acacia species are favored by goats

Tannins are chemical compounds produced by plants during their secondary metabolic processes, which can affect an animal's consumption and digestion of feed (Besharati, 2022). They are classified as hydrolysable tannins and condensed tannins. The strong affinity of plant tannins for proteins has been utilized in ruminant nutrition to reduce protein degradation, enhance protein utilization, and improve animal production efficiency (Huang et al., 2018). The effects of plant tannins on the digestive physiology, nutrition, and microbial community of sheep and goats, taking into account factors such as feed intake and digestibility, have been investigated (Min et al., 2018). Tannin-rich trees and shrubs, such as Acacia *spp*., Quercus *spp*., Terminalia *spp*., Leucaena leucocephala, and Prosopis *spp*., can potentially impact sheep and goat reproduction by affecting the growth and health of these animals (De Angelis et al., 2021). High tannin intake can result in a reduction in fertility in both males and females, delayed puberty in young animals, increased risk of abortion and stillbirths, reduced sperm quality and quantity in males, and potential uterine problems in females, as well as contributing to uterine infections and other reproductive issues (Molino, 2023; Saminathan et al., 2014).

Improving fertility, enhancing growth, boosting milk yield, and promoting tolerance to certain intestinal parasites are just a few of the nutritional advantages of preventing excessive rumen fermentation of dietary protein. Plant-based secondary organic compounds, such as tannins, which are present in forages that are rich in them, have been investigated for their positive effects on animal production and their anti-methanogenic qualities (Jayanegara et al., 2012; Jayanegara et al., 2013). According to Jayanegara et al. (2015), forage legumes that are high in tannins, when fed to ruminants, can contain up to 20% of their dry matter in the form of condensed tannins (CTs). Tropical forages, which have a lower digestibility than temperate forages and possess different chemical and structural makeups, are known to have this characteristic. Kabir et al. (2002) suggested that providing high-protein supplements to grazing sheep and goats can enhance their overall reproductive success. Meza-Herrera et al. (2008) reported that the enhanced ovarian activity caused by the addition of undegradable rumen dietary protein due to tannins is a result of local effects caused by changes in insulin in a non-GnRH-gonadotrophin-dependent manner, rather than changes in LH or GH. Wurlina et al. (2020) investigated the effect of guava leaf polyphenols on spermatozoa motility, integrity, and viability.

A study by Younan et al. (2018) found that adding alfalfa leaf hay (ALH) to Berseem hay did not significantly impact lamb birth weight during late pregnancy stages. However, when Barki ewes were fed dried Acacia leaves during their third trimester, birth weights were lower than average. The study concluded that substituting dried *Acacia saligna* leaves for Berseem hay improved ewe performance and nutrient utilization by up to 60%, despite the lower birth weights in lambs born to Barki dams fed Berseem hay. Ahmed et al. (2021) noted that in recent years, many antioxidants have been proposed as tools to improve male reproductive performance. Antioxidant supplementation is suggested as a means of preventing the oxidative chain reaction and improving the process of spermatogenesis and, thereby, the quality of the sperm and general testicular health. However, the ability of tannins to serve as antioxidants must be balanced against their ability to reduce nutrient digestibility and feed intake in animals (Dschaak et al., 2011). Although such antioxidants are, in most cases, expensive and artificial, tannin extract is a cheap and natural source of antioxidants.

Tannins have been studied with respect to their nutritional significance for sheep and goats, but recent research has focused on the impact of extracted tannins on spematology parameters. Peptides and carbohydrates are expected to form complex linkages with polyphenols, and macrominerals, as well as carbohydrates and lipids, form other complexes (Bunglavan and Dutta, 2013). Protein-tannin complexes are formed at rumen pH, reducing proteolytic activity and protein degradation (Rodriques et al., 2013). Most binding occurs during mastication, but further binding in the rumen involving proteins from other dietary factors may also occur (Besharati et al., 2022; Arbenz and Av´erous, 2015). Tannins can delay the breakdown of plant cell walls and ruminal proteins by binding to dietary proteins and hemicelluloses, including cellulose, hemicelluloses, and pectin. Polyphenols may also interfere with digestion by connecting with bioactive molecules (Mc Sweeney et al., 2001), indicating how supplementation with Acacia saligna reduced cell wall digestion. Goats without prior exposure to a tannin-rich diet have tannin-degrading bacteria in their rumen microflora. Furthermore, rumen bacteria may develop resistance to tannins as a result of chronic exposure (Patra and Saxena, 2011).

Tannin-insensitive bacteria have been found in intestinal ecology, and tannin-resistant bacteria in the rumen protect animals not accustomed to a tannin-rich diet by reducing harmful effects. To manage tanniferous trees and shrubs, moderate browsing should be allowed, mixed grazing should be provided, supplements should be given to counteract tannin effects, animal health and reproductive performance should be regularly monitored, and tree management should be considered (Besharati et al., 2022). The effects of tanniferous plants on reproduction can vary depending on tannin concentration, animal species, and individual tolerance. Consult a veterinarian or animal nutritionist for specific guidance (Saminathan et al., 2014). Tree management should consider removing or pruning tanniferous trees and shrubs in critical grazing areas. To reduce tannin effects on reproduction, ensure moderate tannin intake, balance with other feeds, choose low-tannin varieties, and provide adequate nutrition to mitigate tannin effects. Mix tanniferous plants with other feeds to dilute tannin content, and ensure overall nutritional needs are met.

### 7.5. Willow tree trimming and Populus feeding on small ruminant reproduction

Willow trees, classified under the Salix genus, are a diverse group of deciduous trees and shrubs (Jürgenliemk et al., 2007). Willow leaves and twigs provide essential nutrients, phytoestrogens, and antioxidants for reproductive health. However, salicylates, which can be toxic to small ruminants, can reduce fertility and potentially cause abortion or birth defects (Theorkneynews, 2021). McCabe and Barry (1988) measured the voluntary intake and apparent digestibility of tree willow and osier willow in sheep and goats. The study found that voluntary digestible dry matter intake in osier willow was 22% less than in tree willow, due to higher concentrations of lignin and condensed tannin. This lower digestible dry matter intake was due to lower voluntary intakes and lower digestibility of the dry matter.

Secondary growth willow also had lower voluntary intake and apparent digestibility than primary growth (Muklada et al., 2020). However, goats had approximately double the voluntary metabolizable energy intake of sheep, both for primary growth and secondary growth willow, due to consistently higher voluntary D.M. intakes and higher digestibility. The guidelines for feeding Populus to small ruminants include limiting feeding to moderate levels (10-20%), trimming willow trees to minimize salicylate concentrations, mixing willow with other feeds to dilute salicylate intake, monitoring animal health and reproductive performance, and consulting a veterinarian or animal nutritionist for advice on willow inclusion (Muklada et al., 2018).

**Fig. 10.** Weeping willow – (*salix babylonica)*

Mcwilliama et al. (2005) assessed the ability of sheep to reproduce while grazing poor-quality water-stress pasture with sources of feed for poplar and willow. This study aimed to confirm the interference from poplar leaf rust, which may contain an undetermined oestrogenic compound. The poplar addendum seemed to have no effect on the rate of reproduction since it contained low CT as well as other anti-nutritional factors. The higher rate of sheep reproduction caused by supplementing poplar is most likely explained by a combination of these mechanisms, most notably the likely increased protein absorption. Willows grown in spring and summer can be used as supplementary feed during summer droughts, particularly when fed to goats. Tree willow is preferred over osier willow, as it is less efficient due to high concentrations of lignin and condensed tannin, which limit the nutritive value of the leafy osier willow, similar to Lotus pedunculatus (McCabe and Barry, 1988).

## 8. Effects of the price and supply of conventional feed resources in sheep and goat production

The fluctuation of conventional feed resources for sheep and goats has prompted producers to explore alternative feed options for improved reproduction. To address the issue of balancing the supply and demand for these critical feedstuffs for sheep and goats to improve reproduction, it is essential to use novel feedstuffs to the greatest extent possible and incorporate them into small ruminant production systems, as recommended by Ben Salem et al. (2004). The two principal constraints to the expansion of sheep and goat productions and the associated reproductive efficiency are the high cost of concentrate feeds, such as oil seed meal and grains, and the scarcity of high-quality green fodder during the prolonged dry season, as noted by Sayed-Ahmed et al. (2018). Furthermore, conventional/traditional feed supplies, such as grains, cereals, legumes, etc., for sheep and goat production are scarce and expensive in many parts of the world. As a result, it is critical to look for unconventional, alternative feed sources that may provide helpful ingredients for animal diets, as suggested by Szumacher-Strabel et al. (2011) and Zhou et al. (2012).

In different agroecosystems in the arid tropics, the use of local alternative sheep and goat feed resources is becoming increasingly important for reproduction and productivity, as noted by Silanikove (2000) and Melesse et al. (2009). Shrubs and their byproducts are increasingly recognized as crucial feedstuffs for sheep and goats, especially in developing countries with challenging weather conditions, and as protein sources, as reported by Chisoro et al. (2020a) and (2020b). Since feed quality directly affects reproductive efficiency, especially in sheep and goats, it is essential for the success or failure of animal reproduction.

## 9. Prospects for future study on the contribution of feed resources to optimizing the reproductive efficiency of sheep and goats

Future research is necessary, particularly in sub-Saharan Africa's drought-prone areas, to explore the relationship between feed availability and reproductive efficiency in sheep and goats. This includes investigating the effects of feed scarcity caused by drought on reproductive performance, assessing feed-based interventions to improve reproductive resilience, examining the role of reproduction as a coping strategy for drought stress, and determining the potential of reproductive technologies like artificial insemination and embryo transfer to improve drought tolerance. Innovative strategies to enhance the resilience and reproductive efficiency of sheep and goat farming systems in these areas may result from such studies.

Research should also focus on how feed resources affect the rumen microbiota and how that affects reproductive efficiency. Understanding feed-fertility interactions, particularly those involving feed resources, reproductive hormones, and reproductive processes, is also important to maximize feeding strategies. In underdeveloped countries where feed resources are scarce due to changing climate conditions, using non-traditional feed resources may be a viable option for achieving optimal reproductive efficiency in raising goats and sheep. Additionally, it is important to examine how using unconventional feed sources can increase reproductive efficiency while having a smaller negative impact on the environment.

Scholars may devise innovative strategies to improve reproductive efficiency in sheep and goats while mitigating environmental effects by exploring alternative feed sources and understanding the nutritional factors that influence reproductive function. Unique nutritional compositions from non-traditional feed sources may enhance reproductive performance. Furthermore, it is crucial to investigate how genetic differences in sheep and goats affect their response to various feed sources and their reproductive outcomes. This will aid in the development of feeding plans tailored to the specific needs of animals based on their genetic makeup, reproductive history, and environment.

## 10. Implications

Nutrition is crucial for improving sheep and goat reproductive efficiency, requiring the use of appropriate feed resources and dietary management practices. Strategies include formulating balanced diets, supplementing key nutrients, managing body condition, and minimizing stress. Non-traditional feed resources, such as tree parts, are becoming increasingly common in tropical and subtropical regions due to their cost and potential anti-nutritional elements. Feed quality is crucial for small ruminant production, especially in sheep and goats. As sheep and goat production becomes more expensive, producers are exploring alternative feed sources, such as willow cuttings, lupin seed, feed blocks, and alternative pasture species. These sources may provide energy and protein but may contain plant secondary compounds that affect reproductive cycle components. The intake requirements for sheep and goat reproduction efficiency depend on timing and quantity of supplementation. In conclusion, nutrition is essential for supporting sheep and goat fertility and breeding. A deep understanding of their nutritional needs and strategic dietary management are essential for optimizing reproductive performance and achieving successful breeding outcomes. Future research in sub-Saharan Africa should investigate the relationship between feed availability and reproductive efficiency in sheep and goats, focusing on drought-induced feed scarcity, feed-based interventions, and reproductive technologies like artificial insemination and embryo transfer to enhance farming resilience and efficiency.

**Author Contribution**

Conceptualization and writing-original draft preparation of subtopics: NA, CB, PC & EM. All authors edited their subtopics. Proof reading, grammar checking, plagiarism check and reference style, ethical issues consideration, NA. All authors have read and agreed to the published version of the manuscript.

**Disclosure statement**:
No potential conflicts of interest were reported by the authors.
**Data availability statement**
No data were used.
**Funding**
No funding was received.
**Ethical consideration**
The manuscript was carefully checked for all ethical issues concerning plagiarism, consent to publish, misconduct, data fabrication, falsification, double publication or submission, and redundancy of the manuscript.

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**How to cite this article:** Assan, N., Bhakat, C., Chisoro, P., Muteyo, E., 2025. The role of feed resources in optimizing reproductive efficiency in goats and sheep. Pure and Applied Science Advances, 13(1), 1-28.