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Review article

Flushing and reproductive competency in goat and sheep production

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ABSTRACT

The primary fortitude of this discussion is to overview the effect of flushing on reproductive competency in goat and sheep production. Flushing is meant to supply high calorific value and/or proteinaceous feed prior, during, and after mating. It has been a common nutritional management practice among commercial goat and sheep producers to increase ovulation, conception rates, and implantation rates hence the increased number of kids/lambs born. This event is on the premise that there is a strong relationship between nutrition and reproductive performance in goats and sheep. Like sheep, goats also have high chances for multiple ovulations, but this potential may be compromised by nutritional stress experienced prior, during, and after mating. Since ewes/does nutritional demands fluctuate throughout the reproductive cycle, strategic feed supplementation (flushing) can be an essential management tool to improve reproductive efficiency. The basic understanding is that fortified nutrition, especially energy, just before and during the early breeding season increases the ovulation rate and hence the lambing or kidding rate. Twinning and triplet at birth are sometimes a clear indication of increased ovulation rate due to flushing. Some of the factors that influence flushing are a dietary source, body weight and scoring, and timing and duration of flushing. Compared with a high-calorie diet, a high-protein diet can increase the ovulation rate of the ewe/does. Satisfactory body condition is critical for acceptable conception rates, however outside certain biologic limits, flushing is not effective. Supply of high proteinaceous and high calorific value feed prior, during, and after mating does not always increase lambing or kidding rates; but may enhance the number of females cycling early in the breeding season, consequentially in the birth of a larger portion of the offspring early in the lambing or kidding season. From this discussion can conclude that flushing has a significant influence on the reproductive performance of ewes/ does.

1. Introduction

The feed flushing system has been incorporated into the sheep and goat management system to increase the seasonal breeding period (Seegers et al., 2011). This is on the realization that the interaction between nutrition and reproduction have a major role in goat and sheep reproductive performance (Somchit et al., 2007). Prior and during mating, the practice of flushing ewes/does was used with some success (Chowdhury et al., 2002; Karikari and Blasu, 2009). Flushing is short-term feeding management practice that focuses on the supply of high proteinaceous and high calorific value diets prior, during, or after mating (Barhanie et al., 2020). Rekik et al. (2007) working with goats and sheep reported that short, medium and long-term dietary alterations can influence reproductive parameters. Evidence suggests that nutrition is generally a major regulator of reproduction (Smith and Akinbamijo, 2000) hence provision of extra feed to increase nutrient intake particularly preceding mating (flushing) is known to improve reproductive performance due to dynamic effects of nutrition on ovulation rate (Kusina et al., 2001). In this regard, flushing/stimulation is a preferred option for the management of reproduction through modulating some aspects of reproductive activities (Fatet et al., 2011).

In the Mediterranean region, breeding patterns of sheep and goat breeds differ significantly in food availability over other environmental cues (Folch et al., 2000). Nutrition directly influences reproduction through mechanisms such as ovulation and conception rates (O'Callaghan et al., 2020). Reproductive efficiency increased by flushing which promoted ovarian activities namely an increase in folliculogenesis and higher ovulation rate (Shaukat et al., 2020). This is an indication that some reproductive parameters are dependent on the availability of nutrients (De Santiago-Miramontes et al., 2011). Ovulation rate is a vital determinant of fertility in females hence increasing the number of eggs released in a cycle increases the chances of multiple pregnancies. Flushing indirectly affects reproductive performance through blood metabolites and hormones (Robinson et al., 2006) hence several nutritionally associated signals work as messengers fundamental in the reproduction process exists (Hess et al., 2005). Response to flushing are often variable and inconsitence depending on factors such as genotype (Mellese et al., 2013; Cheminneau et al., 2004), body condition of an animal (O'Callaghan et al., 2000), timing and duration of flushing (Sabra and Hassan, 2008; Karikari and Biasu, 2009), the amount and quality of dietary supplements (Acero-Camelo et al., 2015). This discussion focuses on reproductive competence in response to flushing in goat and sheep meat production.

According to Ferrell (1991), nutrition can determine whether an animal ovulates or exhibits oestrus. This is in line with observation by McDonald et al. (1995) who proffered an endocrinological explanation of the effect of flushing. De Santiago-Miramontes et al. (2008) observed that satisfactory feed intake resulted in a higher proportion of insulin production, believed to promote the uptake of glucose and the synthesis of steroid hormones by the ovary. Elsewhere, nutritional flushing improved ovulation and fetal implantation in the uterus (Fitz-Rodriguez et al., 2009; Urrutia-Morales et al., 2012). Animals with a higher plain of nutrition were observed to have a longer breeding season, by about one month (Zarazaga et al., 2005). Overall pregnancy and ovulation rates were lower for does under nutritional stress (Mani et al., 1992). Naqvi et al. (2011) observed that flushing before mating increases ovulation rates and lambing percentage in many sheep breeds, while Acero-Camelo et al. (2008) recorded a 23% higher lambing rate working with flushed Merino breeds of sheep for three weeks. Elsewhere, the conception rate was (79.2%) and 66.7, respectively, in flushed and unflushed ewes (Chaturvedi et al., 2000). Khili et al. (2017) used adult prolific Barbarine to investigate the efficacy of nutritional supplementation on reproductive success in an out-of-season mating system in sheep. It is concluded that a three-week supplementing period before to the introduction of rams is effective in achieving high reproductive performance in the Barbarine breed's prolific strain. The review looks at reproductive competency in response to flushing in goat and sheep production.

2. Flushing from nutritional management point of view

Flushing is a well-managed flock's nutrition and reproduction program to ensure that female sheep gain an appropriate amount of weight before being mated. It is utilized to increase the conception rate of the flock and ensures that more ewes that are mated conceive. The practice of flushing is predicated on the understanding that there's distinct relationship between nutrition and reproduction and their interaction has far fetching implications for reproductive competency in goats and sheep. Hence getting the proper nutrition at the proper time is important for the reproductive success that drive profitable production of sheep and goats. Viability of goats and sheep enterprise are dependent on a need to produce a high percentage of lamb/kid crops, that pull through weaning while developing satisfactory replacement animals. An ideal flushing feeding practice which is efficient and economical, will minimize reproductive related losses across all stages of reproductive processes. To be successful, goats and sheep producers need to understand nutritional requirements at different life stages (Figure 1). Therefore, knowledge of the role of essential nutrients (energy (fats and carbohydrates), proteins, vitamins, minerals, water, fiber) at different stages of an animals' reproductive cycle in critical.

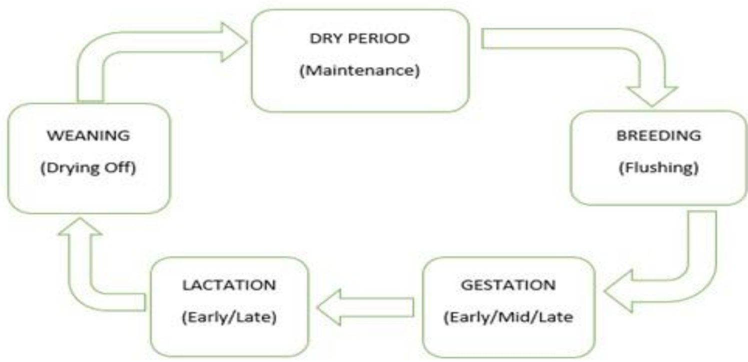

Fig. 1. Stages of production in ewes/does which define their specific nutritional requirements.

Time of flushing is very important for its success. It is meant to temporary but purposeful elevation in the plane of nutrition around breeding time, with the idea of boosting ovulation, conception and embryo implantation rates. Flushing may also increase the proportion of females that exhibit estrus. Flushing should begin around 45-60 days before breeding and continue into the first stages of gestation. Special feeding usually begins around 2 weeks prior to breeding and continues at least 2 to 4 weeks into the breeding season. Flushing aims to bring ewes' body condition scores up to 2.5 to 3.0 before breeding and into the first stage of gestation. As ewes enter different production stages, their target BCS changes - and changes to their diet should follow suit. This 1-5 scale is especially useful before breeding as energy requirements and BCS goals increase. Getting ewes to this condition can lead to optimal conception and embryo survival rates. Feeding energy-rich supplements (Webb and Mamabolo, 2004) is desirable, with the option of being high in protein if the veld they are grazing on is deficient in protein. In this case metabolizable energy concentration in the diet from about 2 megacals per kg to 2.1 or a total of 1.4 megacalories of metabolizable energy per day.

The National Resource Council (NRC) established a fairly precise set of nutrient requirements for sheep for various stages of production and with different levels of productivity. In sheep for flushing a ewe weighing 60 kg will need DM (1.8kg) intake, TDN (1.04kg), ME (1.7kg), CP (0.14kg). Ca (5.7g) and P (3.2g) (NRC, 1985). Requirements presented should be used as guidelines and not as rigid standards. Energy restriction suppresses the increase in LH that is necessary for growth of ovarian follicles in the preovulatory stage (Schillo, 1992). Flushing with protein is advantageous if flocks are on a protein-deficient diet such as a low-protein pasture. Maintaining protein levels between 10-16% of the total diet is ideal for reproductive health. Response to flushing is greatest in animals with below-average BCSs, especially those that were stressed by heavy lactation. The practice may have utility for dams in poor body condition, but there does not appear to be justification for flushing does in acceptable body condition. Apart from body condition (thin does/ewes respond more than those in above-average condition) (Birhanie et al., 2020), greater effects of flushing are also dependent on flush diet (Allaoui et al., 2018), age of the ewe (mature ewes show a greater response than yearlings), genetic background or breed (prolific breeds are least responsive) (Berhane and Eik, 2006) and stage of the breeding season (greatest response is seen early and late in the breeding season).

Flushing time is very important for reproductive success. The idea is to increase ovulation, conception, and embryo implantation rates, with the goal of increasing temporary but targeted nutritional levels before and after the breeding period. Flushing can also increase the proportion of females coming into estrus. Flushing should begin approximately 45-60 days before breeding and continue until early pregnancy. Special feeding usually begins about 2 weeks before breeding and lasts at least 2-4 weeks until the breeding season. Flushing is aimed at achieving a sheep and goats body condition score of 2.5-3.0 before breeding and in the early stages of pregnancy. As the ewes enter different reproduction stages, the target BCS tend to change and dietary changes should follow suit. This 1-5 scale is useful before breeding, which is especially useful when energy demand and BCS goals are increasing. Putting the females in a sound body condition provides optimal conception and embryonic survival. It is desirable to give high energy supplements (Webb and Mamabolo, 2004), and if the grazing is deficient in protein, have the option of elevating protein supply. In this case, the concentration of metabolizable energy in the diet can range from about 2 megacals per kg to a total of 2.1 or 1.4 megacalories of metabolizable energy per day. The National Research Council (NRC) has established a fairly accurate set of sheep nutritional requirements at different stages of production and at different levels of productivity. For flushing sheep, 60 kg ewes require DM (1.8kg) intake, TDN (1.04kg), ME (1.7kg) and CP (0.14kg). Ca (5.7g) and P (3.2g) (NRC, 1985). The requirements presented should be used as guidelines, not as strict standards. Energy limitation suppresses the LH surge required for follicle growth in the preovulatory stage (Schillo, 1992).

Maintaining protein content during 1016% of total diet is ideal for reproductive health. Responses to flushing are greatest in animals with below average BCS, especially those stressed by intense lactation. This practice may be beneficial for sick dams, but there seems to be no reason to wash away acceptable females. Besides physical condition (thin females / ewes are more responsive than above average) (Birhanie et al., 2020), the greater effect of flushing is on flushing (Allaoui et al., 2018) and age. It also depends on ewes (adult ewes show a greater response than 1-year-old), genetic background or varieties (productive varieties are the least responsive) (Berhane and Eik, 2006), and breeding season (maximum). The reaction is observed in the early and late stages of reproduction season. Evidence on the beneficial effects of nutrition on reproduction in goats and sheep is overwhelming (Forcada and Abecia, 2006). In particular, nutrition is one of the main factors affecting reproductive process such ovulation rate, pregnancy establishment, embryo development and survival until parturing (Petrovic et al., 2012) and in males' nutritional stress has been associated with reduced sperm quantity and quality. Nutrition provision that supply a balance for all nutrients and meeting all known nutrient requirements is essential for successful reproduction (Chagas et al., 2007). The effects of nutrition on reproduction in goats and sheep have been documented by various researchers (Musa et al., 2018; Daghigh Kia et al., 2012; Marais, 2011; Godara et al., 2010; Sabra and Hasan, 2008).

Reproductive parameters namely entry into breeding activity, ovulation rate, conception rate, embryo survival, and fetal development are affected by nutritional level and diet composition (Gootwine, 2016), hence it is sufficing to suggest that monitoring nutrition is critical for reproductive management. The influence of nutrition has an overlapping effect on reproductive processes and this is inclusive of the formation of the foetal gonads, their post-natal development, the timing of puberty and in multiple ovulating species, their ovulation rates (Robinson et al., 2006). Nutrition can directly influence reproductive performance through the processes of oocyte development, ovulation, embryo survival and conception rates. The indirect implication of nutrition is manifested through its influence on some hormones and metabolites which support reproductive processes (Robinson et al., 2006).

Nutrition has a direct effect on reproduction in goat and sheep, in addition to the its role to mitigate the effects of other factors. The interaction of nutrition and reproduction reproductive efficiency readily lend itself to manipulation to ensure positive outcome for goat and sheep production (Somchit et al., 2007). This has resulted feeding levels probably contributing to most variation in reproductive performance between flocks and among animals within flocks (Holness et al., 1978). However, it should be noted that nutrition does not influence reproduction as a sole influence other factors namely genetics and physical environment also play their role in improving reproductive efficiency in goats and sheep. Rightful nutrition could prop up mediocre biological animal types to attain their genetic potential, and may even obscure the adverse influence of a prevailing unfavorable physical environment. On the other hand, improper feeding will not only worsen harsh environmental effects, but will also compromise animals' reproductive performance below their genetic competency. One of the strategies in improving productivity in goat and sheep meat production is through appropriate breeding management. Therefore, one way that goat and sheep producers can attain this is by considering flushing into their breeding management practice. Flushing is a short term but focus nutritional management practice which producers can synchronize with breeding time to improve animals' reproductive capacity. The purpose of flushing will be mainly to increase the level of protein and energy around breeding time improves body condition. Ewes kept in good body condition throughout the year can perform at or near their production capacity.

3. Flushing through improved body condition regulates reproductive physiology

Blood metabolites and hormone levels change significantly during the goat and sheep's reproductive cycle and have a major role in regulating reproductive processes. Flushing was associated with significant fluctuations in blood protein, urea, BHBA and estrogen levels. These changes in concentrations of specific metabolites and hormones are associated with improved fertility rates (Chilliard et al., 1998; Scaramuzzi et al., 2006; Ricardo et al., 2000). However, regulation of reproductive function involves the interaction of the nervous and endocrine systems (Senger, 1999). Reproductive function requires the integration of the hypothalamus, pituitary and ovaries to regulate the development of gametes and supporting structures. The hypothalamic-pituitary-gonad axis is the basis of all reproductive functions and follicular development and ovulation predominantly are regulated by neuroendocrine control of the axis. This complex network preside over follicle growth and ovulation, making it vulnerable to the effects of stress, especially nutritional stress (Moberg, 1991). Abadjieva et al. (2011) reported that the reproductive process is determined by multi-hormonal action in addition to sex hormones and gonadotropin hormones, as well as "metabolic" hormones. Suboptimal nutritional is the cause of disrupts the mechanisms of the reproductive hormonal complex or multi-hormonal effects that adversely affect reproduction. With reference to flushing, it affects metabolic status (body condition) which is a major regulator of hormonal reproductive activities but the relationship between the metabolic mediators involved and the systems that control fat storage, food intake, and reproduction is not fully understood (Zang et al., 2005). Therefore, changes in food intake are associated with changes in gonadotropin secretion. Gonadal function also responds to diet-related blood-derived metabolic responses (Rhind, 1992; O'Callaghan and Boland, 1999).

Gonadotropins FSH and LH are key hormones in follicle development, but their nutritional role appears to be minimal. Follicular development is particularly dependent on endocrine support. gonadotropin, follicle stimulating hormone (FSH) and luteinizing hormone (LH); It is produced and released by gonadotropin cells in the anterior pituitary gland. In female sheep, nutrient supply affects the ovarian system and may have a direct stimulating effect on follicle formation independent of changes in circulating FSH (Kendall et al., 2003). As the ovulation rate increases, so does the increase in dietary protein. Circulating FSH levels in the second half of the estrous cycle (Davisetaf, 1981; Ritter et al., 1981). Cumming et al. (1975) no difference was seen in the ewes It is fed in three stages of intake. Memon et al. (1969) and Howland et al. (1966) observed that both proteins and energy enhanced ovulation rate, and also pituitary weight and gonadotropin content was improved, but not in glandular FSH and LH concentrations. Radford etc. (1980) found changes in ovulation rate due to luteinizing hormone feeding, but did not find changes in basal LH levels or frequency of LH pulses during the most recent pregnancy. The LH receptor is a distinct marker of granulosa cell differentiation by FSH, however plays a crucial role for the LH response that induces ovulation. Therefore, it is noteworthy that the synergistic action of IGFI and FSH also increases the expression of LH receptor mRNA (Hirakawa et al., 1999). The number and size of recruited small follicles increased with the high dietary conditions. This indicates that the effects of increased food intake are more likely independent of circulating FSH concentrations (Munoz Gutierrez et al., 2002). The sensitivity of ewes to gonadotropin-releasing hormone (GnRH) is diet (Cumming et al., 1975), but with maintenance diet animals Increased FSH release after GnRH administration. Haresign (1981) reported a similarly increased LH release response to GnRH in long underfed ewes, whose pre-stimulation LH levels were lower than in under fed ewes. Ovulation rate increased, but short-term increases in food did not change either pituitary LH content or plasma LH concentration (Haresign, 1981). The normal pattern of LH secretion arises from impulses that stimulate the growth of the follicle. However, malnutrition suppresses LH secretion. Elsewhere, underfed ovariectomized cattle had the same LH concentrations as non-ovariectomized underfed cattle (Richards et al., 1991), however decreased nutrient intake suppressed LH secretion as a direct effect of the hypothalamic-pituitary gland not as a result of the ovarian hormone feedback mechanism.

Reproductive success is primarily dependent on ovulation rate. Hormonal signals that communicate between the pituitary and the ovary as well as original communication within the ovary between follicles and the oocyte determine the success of ovulation rate. Compared to sheep in poor condition, good body condition was associated with larger follicle sizes, and more follicles displayed estrogens with potential ovulatory capacity (Rhind, 1993). This implies that only a small number of follicles are obstructed, and most of the potential ovulatory follicles prevail in a good state of corpus luteum degeneration. Elsewhere, Scaramuzzi et al. (2006) reported that nutritional flushing also alters the blood concentrations of some reproductive hormones. Again, using the same model, proved that there is a transient increase in FSH and a decrease in oestradiol concentrations in the blood. The changes in oestradiol are particularly evident in the follicular phase of the oestrous cycle. In the ovary, the effect of nutrition is to stimulate folliculogenesis. These changes are associated with intra-follicular alterations in the insulin-glucose, IGF and leptin metabolic systems. The stimulation of these intra-follicular systems leads to a suppression in follicular oestradiol production. The consequence of these direct actions on the follicle is a reduced negative feedback to the hypothalamic-pituitary system and increased FSH secretion that leads to a stimulation of folliculogenesis.

The physiological mechanism of flushing is probably related to insulin-like growth factor. Increasing the calorie content of the diet before fertilization increases the production of insulin-like growth factor I (IGFI) in the liver and ovaries. Somchit et al. (2007) observed that the follicular fluid concentration of progesterone was negatively correlated with the follicular fluid concentration of glucose. This was probably because short-term fed on high protein and energy diet causes an increase in blood glucose and insulin concentration in cyclic ewes and also affect the follicular environment particularly follicular fluid glucose level. Insulin-like growth factor I is involved in cell proliferation and differentiation. More specifically, it is part of a family of insulin-like growth factors that are important for follicle formation, steroidogenesis, and gonadotropin sensitivity (Monget and Monniaux, 1995). Evidences suggests that short term nutritional flushing enhance the levels of of glucose, insulin, leptin and FSH in the blood circulation, while those of estradiol is decreased (Scaramuzzi et al., 2006). Therefore, increasing the presence of glucose circulation has proved to be one of the principal nutrients that regulate ovarian activity (Scaramuzzi and Martin, 2008). Flushing through improved body condition and food intake directly affect gonadotropin profile and hypothalamic-pituitary sensitivity to steroid feedback or inhibin, which affects reproductive activity (Rhind et al., 1991). Brand et al. (1997) reported that nutrition improves the ewes' body condition, which in turn stimulates the secretion of gonadotropins essential for superovulation and increases their chances of giving birth to twins. However, feed restriction during the luteal phase perturbs gonadotropin secretion and may compromise reproduction through a delay in ovarian follicle development. Hypothalamic and stalk median eminence contents of GnRH were not affected by feed restriction at any time period (Alexander et al., 2007).

4. Effect of type of flushing diet and composition on reproductive competency in sheep and goats

Different diets and their compositions have been used for flushing with different consequences that affect reproductive performance. The results from the flushing research were based on differences in the flushing diet (Rekik et al., 2012), and the duration of flushing (Habibizad et al., 2015) as well as the animals' body condition score (BCS) (Gottardi et al., 2014;15). Supplementation with conventional concentrates is economically unsuitable, so more cost-effective and sustainable alternative feeding strategies need to be developed. Flushing ration along with both energizing and protein sources improve sheep and goats' sexual behavior. Walker-Brown and Bocquier (2001) suggested that availability of energy has a key influence on reproductive performance, due to sensitivity of the reproductive axis to the adequacy of nutrition and stores of metabolic reserves. This high-level of flushing concentrated feed induced energy to mate and conceive higher than of those does flushed with low level of concentrated feed and none supplemented. However, flushing with high level concentrate supplementation is not effective to reduce abortion (Birhanie et al., 2020). Energy and protein deficiencies can result in embryonic loss, decreased fetal growth, depressed placental growth, fetal mummification, and the birth of weak young (Edmondson et al., 2012). The inclusion of various ingredients in the diet alters the profile of rumen-fermented and rumen-digested products (Roche et al., 2011). In addition, the supply of ingredients that provide high fermentation energy in the rumen may result in more efficient utilization of dietary protein (Wilkerson et al., 1997) and reduced plasma urea nitrogen (PUN). Concentrations of PUN correlate with ammonia and urea concentrations in follicular and uterine fluid (Hammon et al., 2005), and levels above 19.0 mg dL^{-1} have been shown to adversely affect oocyte (Sinclair et al., 2000) and embryonic development (McEvoy et al., 1997).

Flushing diets containing 17.5% crude protein and 2.9 Mcal/kg of metabolic energy were provided 1 month before and 1 month after the breeding season resulted in improved animal sexual behavior. In addition, such supplements have a positive effect on lamb birth weight and body weight (Fazel and Daghighkia, 2014). Consistent with the findings of Sabra and Hassan (2008), consuming protein sources with average lumen degradation and energy sources in flush rations increased the birth weight of lambs (both male and female). Nevertheless, Webbetal (2010) dietary protein sources reported no significant effect on lamb birth weight. During the mating period, higher lambs (79.2%) and conception rates (73.7%) were recorded by flushing with 1.5% body weight concentrate compared to unflushed ewes (Chaturvedi et al., 2006). On the other hand, flushing with CP of 153 g/ day and metabolic energy of 2.19 Mcal/kg improved both sexual receptivity and fertility of sheep (Fazel et al., 2014). Short-term nutrition with energy and protein sources (27-30% CP) improved the reproductive efficiency Spanish and their crossbred with Boer does under poor body condition (Melesse et al., 2013) in contrast, Amanlouetal (2010) found that the use of protein sources with low rumen degradation in late pregnancy does not play an important role in reproductive rate. It is concluded that short-term, high protein flushing may improve estrus expression, ovarian activity, and metabolic status in PGF2α analog synchronized Ossimi ewes (Hassan et al., 2019). In a similar study, Mahmoud and Hussein (2014) reported that long-term protein release increased the number of small and medium follicles and follicle pulsation, ovulatory follicle size in primary and secondary estrus, and reproductive efficiency in subtropical ewes. Long-term protein release increases the rate of ovulation for the first time, but does not affect the second period of estrus.

Goats with low body condition scores and low live weight require high-energy feeding prior to the breeding season. Kusina et al. (2001) assessed three levels of energy intake. 0.27 (low), 0.53 (medium) and 1.06 (high) MJMU/kg of goats on day 60 of pre-estrus. They found that the twinning rate of low-energy diets was significantly lower than that of high-energy diets ($p<0.05$), but at moderate levels they were best in terms of estrus, fertility, and twinning rates. Exposure to 25% energy restriction for 19 days prior to synchronous estrus affects the proportion of goats entering estrus, reducing ovulation rates and delaying ovulation (Mani et al., 1992). Zabuli et al. (2010) Short-term energy supplementation was observed to stimulate total ovulatory follicle count and ovulation rate. Energy is needed to reduce ovulation disorders and promote multiple ovulations (Beam, 1996). A high-energy pre-pregnancy diet has been well documented to promote oocyte maturation associated with embryonic survival, even when fed a post-mating control diet (Ashworth et al., 2010). Lipid deposition is the main form of energy storage in goats and sheep and is important in determining body condition score (BCS). Therefore, supplementing the flushing ration affects the body condition score and thus the fertility of the animal. Lipid deposition is a major form of energy storage in goats and is important in determining BCS, hence fertility. ElShahat and AboEl Maaty (2010) reported that energy (fatty acid) supplementation significantly improved the number and size of preovulatory follicles in ewes and the rate of ovulation.

Daghighkia et al. (2011) showed that the use of barley and vegetable oils can be seen as an energy source for flushing rations that improve dam fertility and pregnancy. In their study, Birhanie et al. (2020) females flushed with 450g and 300g of wheat bran per day mixed with 50g of nut cake (G. Abyssinica) showed high conception rate (70-80%) and kidding rate (70%). This high-level concentrate flush induced higher mating and conception rates than those flushed with low levels of concentrate or without supplements. However, high concentrate supplementation is not effective in reducing abortions. Feeding animals lush grass and feeding them high-energy supplements are both flushing options (Johnson, 2001). Naqvi et al. (2011) working with grazing sheep which were fed poor quality dry forage, supplemented during flushing periods, and found that nutritionally poor dams gained weight efficiently and quickly. Rankins and Pugh (2012) reported that flushing can be acquired by providing fresh pasture or supplementing approximately 0.14kg to 0.45kg with 10% to 12% crude protein grains/head/day. It is best to start super feeding about 2 weeks before the male is released and continue for another 2-3 weeks until the breeding season. In a similar study, Kulkarni et al. (2014) working with Osmanabadi goats fed an additional supplement of 250 g/doe/day compared to farm-reared goats, and reported a 10% improvement in kidding rate.

Fouladi-Nashta et al. (2009) and Ricardo et al. (2000) observed that supplemental fats were a vital precursor for the synthesis of reproductive hormones like steroids and prostaglandins because they enhanced ovarian follicle development and endocrine gland activity. This was confirmed by Safdar et al. (2017) who supplemented saturated and unsaturated fatty acids, especially in their CSFA forms during flushing period, and improved the reproduction problems induced by progesterone deficiency, lack of durability of the fetus due to hormonal instability, and abortion control factors. It was concluded that supplementing the flushing diet with calcium salts of fatty acids (CSFA) increased blood metabolites and hormones related to reproductive performance; and improved fertility, lambing rate and ewes of CaFL treatment have the highest number of lambs (16 lambs) between different groups. Elsewhere, dietary fat was associated with elevated progesterone concentrations (Ricardo et al., 2000; Clair Wathes et al., 2007; Staples et al., 1998). In contrast, Titi and Awad (2007) reported no relationship between fat intake and blood progesterone concentrations, while, Staples et al. (1998) reported that plasma concentrations of estradiol were not influenced by different fat sources.

Nottle et al. (1997) found that pre-ovulatory lupin grain supplementation (500g per ewe per day) given during the last 10 days before mating produced an average of 0.57 additional ovulations per ewe. Six days after supplementing the merino sheep diet with 750g of lupin grains per day, increased ovulation rate by 25-30% (Gootwine, 2016). Both high-energy, high-protein feeds such as high-energy and protein grains and lupin grains, or equivalent high-nergy, high-protein commercial feeds such as beans and oilseed meals promote reproduction. Sakly et al. (2014) working with Barbarine ewes reported that ewes fed nutritional regime including cactus performed similarly to those receiving diets including conventional concentrate feeds. Ewes receiving cactus had higher number of large pre-ovulatory follicles, between days 14 and 19 after introduction of rams, than females in the CC and S ewes. However, there were no differences in the onset of oestrous behaviour in response to 'male effect' or in the number of corpora lutea (Sakly et al., 2014). In a similar study, Rekik et al. (2012) investigated the effects of cactus cladodes supplementation on follicular dynamics and ovulatory response in semi-arid sheep. Following that, ovulation rate was modified by supplementation length, being higher in sheep fed cactus for 6-10 days than ewes fed cactus for more than 11 days, in sheep fed concentrate for 6-10 days, and even in animals subjected to traditional concentrate flushing. Figueira et al. (2020) working with tropical Santa Inês ewes to assess the effect of replacing ground corn (402 g kg-1 of dry matter) with rehydrated corn grain silage (RCGS; 425 g kg-1 of dry matter) in a flushing diet on follicular development found out that the diameter of ovulatory follicles at sponge removal, the interval from sponge removal to estrus, and the growth rate of the ovulatory follicles were greater in the RCGS group than in the control group, resulting in larger follicles at ovulation. Replacing ground corn by RCGS in the flush diet did not increase the number of ovulations, but delayed the onset of estrus and ovulation of larger follicles.

5. Flushing improves body condition while influencing ovulation and conception rates

Flushing, or giving supplementary feed to ewes before breeding, has been shown to enhance ovulation rate and embryo survival in sheep (Johnson et al., 1990). Hashem (2012) found that short-term supplemented (flushing) does had an average total follicle count increase of approximately 19.8%, an average ovulatory follicle count increase of 30%, and an ovulation rate increase of 50%. Feed supplementation before or during mating has a positive effect on body condition, fertility and ovulation rate and ovulation rates immediately (Chowdhury et al., 2002; Karikari and Blasu, 2009). West et al. (1991) reported that ewes maintained in good body condition throughout the year are able to perform at or near their production potential. The maternal nutrition through its effect on body condition is one of the factors that strongly influences ovulation rate (Montgomery et al., 1985). Cumming (1977) provided evidence suggesting that the average ovulation rate per ewes increased from 0 to 0.44 per 10kg of body weight gain, suggesting that both body weight and physical condition could be used to predict ovulation rate. Gunn and Doney (1975) determined the interaction between ovulation rate and diet and body condition in sexually mature Scottish blackface ewes. These authors concluded that ovulation rate was positively correlated with body condition during mating, but not with prior feed intake. The ovulation rate of the ewes weighing 57.5kg was 1.93, while the ovulation rate of the ewes weighing 39.3kg was 1.00. In addition, light ewes returned to service more often than ewes in good condition.

Widayati et al. (2011) observed significant effects of ewes' body condition scores on gonadotropin secretion, follicle and corpus luteum growth and development, and ovarian activity (Widayati et al., 2011). Prior to mating, enhancing ewes/does nutritional status with high-quality feed resources ensures that they gain weight and improve their physical condition, which improves estrus activity, ovulation, and conception rates. Protein or energy-based supplemental feeding (flushing) during mating usually improves reproductive performance by increasing the expression of goat estrus, conception, fecundity and twin proportions (Kusina et al., 2001; De Santiago Miramontes et al., 2008; FitzRodriguez et al., 2009; Hafez et al., 2011). In the ewe, short-term nutritional supplementation stimulates folliculogenesis (Somchit et al., 2007) and increases ovulation rate (Letelier et al., 2008), these results are in line with the research in sheep where short-term energy supplements stimulate folliculogenesis, only 30-50% of treated ewes will convert increases in follicle number to increased ovulation rate.

Chaturvedi et al. (2000) discovered that the conception rate in flushed ewes became greater (79.2%) than in non-flushed ewes (66.7 percent). Kenyon et al. (2009) reported that BCS circumstance rating influenced ovulation and conception rates, in addition to the amount of embryos and lambs born (2014). According to Gonzalez-Bulnes et al. (2004) dams with low BCS because of undernutrition will be predisposed to mobilize and divert their restrained body reserves towards different crucial physiological and metabolic activities out of bounds of neuroendocrine ovarian activation and prolong anoestrous (2011). Unflushed dams had a shorter and false start of oestrus prior to synchronization, in addition to reduced pregnancy and ovulation rates (Mani et al., 1992). For pre-mating feeding or flushing, Naqvi et al. (2011) harmonious with, it increases the ovulation rate in sheep and the birth of lambs. Greyling (2000) discovered that in Criollo does in good body shape, the postpartum anoestrous phase was shorter than in skinny does. Mellesee (2013) in low BCS, multiple birth in Spanish breeds was visibly lower than crossbred does across treatment diets suggesting possible lower ovulation rates or elevated embryonic losses. In the Spanish Manchega breed, the influence of BCS in fertility has also been noted (Montoro, 1995). A moderate to high and steady improved body condition, according to De Santiago-Miramontes et al. (2009), can stimulate estrus activitie and ovulation rate. High body condition scores are related to increased ovulation in Mediterranean breeds, especially early in mating (Forcada et al., 1992). Flushed Corriedale, Merino, and Romney sheep increased ovulation rate by 2% per kg of weight. Fraser and Stamp (1987) found that the higher the ovulation rate, the upper the body weight gained as a result of the increased consumption of concentrate. Gunn and Doney (1975) evaluated the reproductive performance of ewes in good, moderately good, and poor health at the time of joining when working with Scottish black-faced ewes. Ewes in low body condition had a suppressed or delayed oestrus, no matter the extent of nourishment that they had before entering, within the same study, a far better body condition was connected to more ovulation.

The ovarian follicles depart the primordial pool approximately 6 months earlier than ovulation. The charge of ovulation may be decreased if dams are poorly fed at this time (Robinson et al., 2002). Improvement withinside the dietary supply of the does, in particular, earlier than mating (flushing), is thought to enhance fertility in small ruminants because of dynamic consequences of food regimen on ovulation charge (Kusina et al., 2001). Reduced ovulation due to malnutrition approximately months earlier than mating, on the alternative hand, becomes now no longer as speedy compensated for via way of means of short flushing. This becomes maximum in all likelihood as a result of their terrible body condition circumstance previous to mating, which they had been not able to get better in time. As a result, their genetic capability for ovulation charge become now no longer realized. This ration is given to animals one month earlier than and after the breeding season to now no longer most effective complement dietary inadequacies, however additionally to elevate the fertility % via way of means of exposing extra does to more does to bucks and increasing the proportion of kidding.

6. Flushing improves body condition which influences pregnancy, lambing/kidding and litter size in sheep and goats

Yilmaz et al. (2011) observed the important effects of BCS on pregnancy rates, lambing rate and fecundity. Optimum pregnancy rate, lamb birth rate, and fecundity were experienced between 2.01 and 3.00, the minimum rate for these parameters was 1.50 or less. A study of inseminated Rasa Aragonesa ewes (Bru et al., 1995) found the lowest pregnancy rate (32.7%) in sheep with a BCS of 2 and a mean BCS (48.3%) from 3 to a BCS of 3 or more. If it is large, 2 and the highest value (58.8%) were found. While the kidding percentage is determined by several factors, much of the variation between comparable flocks' results from differences in percentage of goats ovulating, which is influenced by their body condition and plane of nutrition (Mellado et al., 1996; Fitz-Rodríguez et al., 2009). This is an indication that fortified nutrition especially energy, incontinently before and during the breeding season increases ovulation rates and therefore increases pregnancy rate and lambing/kidding rate. However, a dam's age, body condition score condition, and timing affect her response to flushing (Hoversland, 1958). The ewes deserve better pre-mating feeding to improve their body condition. This promotes the release of the gonadotropin hormone required for hyper-ovulation, increasing the likelihood of high lambing rates and twins. Additional feeding also stimulates post-lactation estrus faster and more strongly (Brand et al., 1997).

Galmessa and Prasad (2002) found that weight gain from enrichment supplementation led to increased fertility of Holo ewes (due to twin births and triplets). Muthuramalingam et al. (2014) observed that high plane flushing diet increased the kidding rate by 10%, and found that this response was due to higher maternal weight gain. Feed flushing (Younis et al., 1978; Landau and Molle, 1997; Branca et al., 2000) increased the proportion of lambs and twins, especially in the dry season when feed resources were scarce and semi-dry (Gunn and Dony, 1979; Thomson and Bahhady, 1988). Hoversland (1958) studying lambs over the three-year period, flushing resulted in a reduced proportion of single births, an increased proportion of multiple births, an increased lambing percent based on ewes bred and alive at lambing and an increased lambing percent based on ewes lambing. This was experienced across age groups.

Nutritional requirements during pregnancy is essential to support placental and foetal development, which is vital for lamb survival (Mun˜oz et al., 2009). The lower pregnancy rates observed in underfed ewes could be mediated through this alteration in the signal of maternal recognition of pregnancy (Abecia et al., 1999). Dam's energy needs vary throughout the reproductive cycle. Ovulation does not increase the energy demand of the ewes, and during the first three months of pregnancy, energy consumption increases by only 3 percent. However, in the last two months of pregnancy, pregnancy accounts for 20% of energy consumption (Fierro and Bryant, 1990). To achieve the best breeding results, the animal's diet must be appropriate for the stages of its breeding cycle (Blache and Martin, 2009a).

7. Flushing influencing birth weight and weaning weight in sheep and goats

When BCS is low due to non-flushing, dams experience low conception rates, low kidding rates, and low weight at birth and weaning (Luginbuhl and Poore, 1998; Urrutia Morales et al., 2012). Flushing may be maintained during pregnancy, but it increases fetal growth and survival and affects birth weight (Liker et al., 2010). Weight changes in pregnant dams often indicate prenatal development of the fetus, as evidenced by the significant correlation between offspring birth weight and maternal weight (Bosso et al., 2007). According to Prasad et al. (2016), flushing of does increased the birth weight of Malabari progeny by 1.08kg. Flushing ewes before breeding resulted in a significant increase in the average daily gain of lambs before weaning, according to Idris et al. (2011). Vatankhah et al. (2012) discovered that increasing sheep BCS during mating resulted in increased total litter birth weight and total litter weaning weight, with maximal values at BCS of 3.5. We must avoid letting the young ewes lose too much BC before mating in order to ensure that they are in in enough condition at parturition to maximize their output. According to Khan (1993), a greater BCS pre-lambing resulted in a higher total litter weaning weight. It is accomplished by separating 1.5-year-old ewes from adults and sorting them according to BC. Prasad et al. (2016), who found that Malabari lambs gained more weight (1.78kg) after eight weeks of weaning. It may be concluded that the difference in mean body weight is solely due to the beginning body weight differential. This suggests that flushing has a long-term impact on progeny's future body weight growth.

8. Flushing response on reproductive success is dependent on genetic background

Early and late maturing breeds can have markedly different live weights and have similar body condition scores. Conversely, animals of similar live weight may differ in condition score. This implies breeds would differ markedly in both biological and economical response to the same feeding (flushing) regime with possible variation in reproductive consequences. Body weight for ewes/does from large breeds may be identical to that of ewe/does from small breeds, but the level of body fatness will be very different. The smaller breeds will carry a great deal more fat at the same weight than the larger breeds. Hence it might be reasonable to suggest that the response to nutritional flushing on body weight may differ with breeds as a result its influence on reproductive capacity. This is addition to the fact that there is defined variation of reproductive efficiency in different breeds. Lassoued et al. (2004), showed important interactions between genotype and level of nutrition. West et al. (1991) reported that the effect of nutrition on uterine efficiency are more varies with breed. This may imply that genetic makeup might be a major determinant mediator on the relationship between nutrition and reproduction.

The impact of season and nutrition on the ovulation rate varies between breeds, where ovulation rate will respond more positively to an improvement in nutrition in some goat breeds more than others (Fatet et al., 2011). It is also possible that different breeds with known genetic backgrounds may respond uniquely to flushing (Sormunen-Cristian and Jauhiainen, 2002). The number of foetuses increases with BCS. However, BCS objectives might vary with the breed of sheep, where some sheep have a lower optimal BCS than others. Ewe breed is also a significant source of variation in fertility after AI (Donovan et al., 2004; Fukui et al., 2007; Papadopoulos et al., 2005; Salamon and Maxwell, 1995).

Differences in the meantime of ovulation and ovulation rates in different breeds of ewes at differences locations may explain the variation in fertility (Salamon and Maxwell, 1995). Meyer et al. (1994) reported that crossbred ewes usually have higher uterine efficiency than their straightbred counterparts. Kenyon et al. (2014) working with various sheep breeds observed a strong relation between body condition score (BCS) and varied measurable reproductive traits. In this sense, in highly prolific ewes like D'Man breed, higher levels of nutrition prior to and during mating were associated with improved reproductive performance, but in low prolific breeds such as Queue Fine de l'Ouest, neither ovulation rate nor lambing rate were affected by the dietary treatment. It is also possible that different breeds with known genetic backgrounds may respond uniquely to flushing (Sormunen-Cristian and Jauhiainen, 2002).

9. Ignoring flushing will compromise reproductive activities due to the ewe/does poor body condition

Endocrine responses to nutritional stress generally tend to suppress reproduction in addition to growth and reproduction, and promote maintenance and survival (Rivest and Rivier, 1995; Strakis et al., 1995; Lindsay, 1996). It is well known that diet regulates reproductive endocrine function in many species, including sheep (Polkowska, 1996). Nutritional levels and peripheral progesterone levels are inversely related in ewes (Parr, 1999; Lozano, 1998). Estrogen levels may be due to decreased follicle development caused by suppression of peripheral concentrations of gonadotropins (Gougeon, 1996). This reverse relationship between food intake levels and plasma progesterone levels is due to differences in the metabolic clearance rates of progesterone (Parr et al., 1993). The findings of Forcada and Abecia (2006) on differences in clearance rates rather than differences in secretion levels may explain the apparent reverse relationship between ewes' diet and peripheral progesterone levels.

Deficiency of required nutrients, but not always of high quality, leading to malnutrition (Reid, 1990). Therefore, malnourished animals are animals that have not been fed an adequate amount of proper diet to meet specific nutritional requirements such as pregnancy, lactation, and enhance optimal reproductive processes. Therefore, malnourished animals are at risk because malnutrition is primarily protein and energy deficiency and is a disorder associated with poor body condition (from a nutritional point of view) hence poor reproduction. Various terms such as malnutrition, underfeeding, restricted feeding, under maintenance, and low energy intake are used in the literature to describe the nutritional restrictions imposed on animals that ultimately result in the animal becoming malnourished and their prone to low reproductive success rates.

Flushing is defined as a sharp increase in ovulation rate in pre-mating ewes. In other ruminants, malnutrition has been identified as the cause of long-term estrus (Kaur and Arora, 1984). Low reproductive success rates have been reported in goats and sheep due to under nutrition (Blache and Martin, 2009). However, Martin et al. (2004) observed significant reproductive success in goats and sheep with flushing. Under feeding had an adverse effect on reproduction by affecting multiple reproductive processes at different levels of the reproductive axis (Meiklle et al., 2018). Compromised maternal nutrition during conception altered fetal metabolism in sheep (Oliver et al., 2001), endocrine function (Bloomfield et al., 2004), and growth history (Harding, 1997). The adverse effects of nutritional stress on follicle development, embryo quality, and embryonic maternal signaling were reported by Abecia et al. (2006). Due to the effects of diet on folliculogenesis and ovulation rate, food restriction either delays or prevents the onset of puberty or disrupts the maternal cycle, causing hypogonadism (Scaramuzzi et al., 2006; Sejian et al., 2010). Turns affect all other reproductive processes. Animals with inadequate feeding and later improved diet have been found to be able to rapidly increase fertility (Abecia et al., 2006).

Fatet et al. (2011) reported that malnutrition tends to adversely affect reproduction when nutritional stress leads to long-term estrus and reduced reproduction. In dams, improper nutrition can cause irregular cycles, reduced ovulation, weakness in offspring and addiction, or decreased twins (Petrovic et al., 2012). Terraza et al. (2012) several consequences of reproductive and malnutrition during pregnancy were reported to be poor pregnancy, severe fetal loss, and pregnancy toxemia. In the long run, an unbalanced diet during pregnancy affects the fertility of offspring (Davis and Dodds, 2001; Wilson et al., 2001; Branca et al., 2000). Malnutrition is a major cause of reproductive disorders, but supercharging should be avoided in late pregnancy as it can increase the incidence of dystocia (difficulty in childbirth) (NAAAS, 2013). Under nutrition in late pregnancy leads to weight loss at birth, which reduces the survival rate of lambs and young animals.

Tanaka et al. (2004) reported that high feed intake can increase the reproductive output, while for short- and long-term under-nutrition may exert a negative effect on ovarian activity in goats. While short-term fasting may decrease the follicular growth, high plasma progesterone level and lowers the magnitude of LH and FSH surge in sheep (Kiyma et al., 2004). Under nutrition can cause reduced fertility depending on the required limits and reproductive conditions. Limited feeding resources may cause a decrease in reproductive performance according to the required limit and reproductive status. Feed restriction is causing a decrease in GnRH amplitude, pulse and the capability of low amplitude GnRH pulses to generate a consequence LH pulse in ovariectomized ewes (Dobson et al., 2012). The magnitude of LH and FSH surge in pre-ovulatory stage may be diminished in fasting in ewes. FSH and LH level tend to be decreased in fasted ewes (Alexander et al., 2007). Improper nutrition effects pituitary-hypothalamus ovarian axis that can be stimulated by metabolic meditators like glucose, insulin, GH, IGF-1 and IGFBP (Kiyma et al., 2004).

Improper feeding for example supplies of 60% of dietary requirements for 8 weeks prior to oocyte recovery reduced oocyte capacity and fertilization, and reduced early embryonic development (GrazulBilska et al., 2006). In addition, pre- and early-pregnancy malnutrition during folliculogenesis slows follicle development in sheep fetuses (Rae et al., 2001). These findings can explain the reproductive dysfunction of sheep offspring observed in other studies. For example, prenatal malnutrition (50% of energy requirements) during the first 95 days of gestation reduced the ovulation rate of adult female sheep (Rae et al., 2002). In addition, metaphase to late maternal malnutrition resulted in a decrease in the number of large corpus luteum in female offspring of sheep (Kotsampasi et al., 2009). Survival of embryos can be adversely affected by malnutrition (Martin et al., 2004). This means that it needs to be supplemented at specific times to compensate for the increased ovulation so as not to affect the survival of the embryo immediately after fertilization. Therefore, in order to improve reproductive performance, it is necessary to change the flushing at the time of mating or stop the flushing during the period immediately after mating. The accuracy of this post-mating change remains unknown.

10. Implications

Flushing is a viable option for achieving optimal breeding, as reproductive efficiency is critical for the future growth and sustainability of the goat and mutton production industry. Non genetic factors, such as nutrition and management determine to what extent reproductive potential is expressed and utilized. Chances are high for substantial improvements to be made in goat and sheep reproductive efficiency that can be achieved solely through nutrition manipulation or regulation in form of flushing with high calorific value or protein feed prior, during, and after mating. Goat and sheep meat producers' use of best nutritional management practices often will enhance reproductive efficiency and proper nutrition being paramount among these factors. Hence, its compelling more than ever to continue finding and managing nutrition in order to increase reproductive competency in goat and sheep production. Novel discovery targeted at understanding optimum interactions between nutrition and/or feed intake and reproductive efficiency can address and further increase productivity in goat and sheep enterprise. Of significance is the characterization of the molecular level contribution to orderly ovulation rate and follicle development with regards to nutrition provision in ewes/does as a basis of knowledge relevant to enhance reproductive efficiency.

In the future, it will be essential to utilize modern molecular tools to understand the impact of nutrition on reproductive physiology in order to improve reproductive efficiency. Low birth weight and multiple birth in goat and sheep can be the critical factor between profit and loss. Hence greater attention must be given to nutrition to ensure optimal reproduction and profitability. Of significance is that a balanced nutrition regime will facilitate increased ovulation rate, regularize cycles in females, dam throwing strong offspring and probably increase the chances of multiple birth. Likewise, resumption of ovarian cycles and estrus and embryo survival has been associated with postpartum nutrition. It is apparent that nutrition has a great effect on animal's reproductive efficiency hence the best recommendation to goat and sheep producers is to provide a feeding program that provide a balance for all nutrients and meeting all known nutrient requirements to optimize reproduction. Does and ewes can produce two or more offspring annually, yet regularly miss this criterion hence appropriate nutrition through consistent supply of adequate energy, protein, mineral and vitamins should be a priority for sustainable goat and sheep production.

11. Highlights

- ✓ Nutrition and reproductive efficiency are highly correlated in goat and sheep production hence malnutrition can restrict reproductive efficiency.
- ✓ As a result of loss of body weight and condition due to undernutrition, the onset of puberty is delayed, increasing the post-partum interval to conception, hence interfering with normal ovarian cyclicity by decreasing gonadotropins.
- ✓ Provision of adequate energy, protein, mineral and vitamins should be a priority for propping up reproductive efficiency in goat and sheep production.
- ✓ Resumption of ovarian cycles and estrus and embryo survival is more likely to be optimized with provision of good postpartum nutrition.
- ✓ Systematic synchronization between animal feeding duration and definitive reproductive episodes will bring about maximum benefits of nutrition on reproductive efficiency.
- ✓ Body condition score at kidding/lambing is a consequence of prepartum nutrition and it is critical as it influences the length of postpartum anestrus and probability of pregnancy.

Recommendation

Goat and sheep producers should implement a feeding schedule (flushing) that provide high energy and/or protein, mineral, and vitamin nutrients before, during, and after mating to optimize reproductive efficiency.

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