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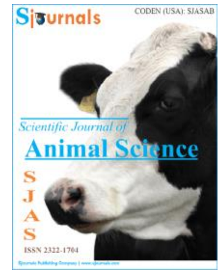

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Review article

Indicators of reproductive performance in goats and sheep meat production

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ABSTRACT

Reproductive performance is a major contributing factor to the efficiency of goat and sheep meat production. Therefore, enhancement of reproductive capacity of goat and sheep flocks is among the most effective mechanisms of increasing the overall meat production. There is an inessential difference between productivity and reproductivity, as almost of the reproductive parameters are the ones that greatly influence production, consequently the viability of any goat and sheep enterprise: stated differently, production is equal to reproduction. Reproductive performance and its interactions on the productivity of goats and sheep flocks, especially with regards to the management of each ewe's/doe's lifetime production (female replacement determination), are structural grantors of a complex biological system that determine meat yield. The principal goal of goat and sheep reproduction is to iterate generations for a specified production intention, first and foremost meat, milk or wool as defined by species or breeds and their crosses and in special circumstances, the production of animals of superior economic priority. Some of the measures of reproductive performance include parameters such as survival rate, prolificacy, sexual maturity, lambing age and interval, conception rates, kid/lambs weaned per year etc. Reproductive characteristics are sensitive to environmental factors as a result can easily adapt to sound flock reproductive management practices. More or less important variables goat and sheep farmers need to attentively consider to promote reproductive performance are age of animals, weather, season, and nutrition. There is evidence that nutrition and management are major determinants of kids'/lambs survival rates, while genetic has been a dominant factor controlling prolificacy. Regardless of the fact that genetics of animals is important in goat and sheep reproduction, reproductive traits are lowly heritable as a result any attempt to genetically improve reproductive efficiency becomes slow and difficult. This entails reproductive efficiency through genetic selection is completely implausible. It is assumed that understanding the measures of reproduction, especially females in order to attain an optimum number of new-born of the required attributes at the most convenient time and at a minimum cost is critical for mutton and chevon producers. The earlier the replacement females starts to give birth to young ones, the more the young ones they produce in their life time, and also the longer the females' productive life as a result contributing to long term flock productivity. Protracted kidding/lambing interval will reduce overall productivity in goats and sheep meat production, while persistent check on reproductive indicators throughout all phases in the reproductive cycle allows producers to adopt husbandry management practices that are meant to optimise overall meat productivity in goats and sheep. The present review gives an insight on some of the indicators of reproductive performance and their possible impact on the overall productivity in goats and sheep meat production.

1. Introduction

Reproductive performance is the productivity of individual animal, or flock in respect of progeny produced, and can be assessed in a number of ways namely prolificacy, fertility, fecundity, interkidding period, conception rates and age at first kidding/lambing (Đuričić et al., 2012). The contribution of reproduction to the overall goat and sheep meat productivity is immense, however its impact is predominantly dependent on the genetics of animals, along with other various non-genetic determinants essentially nutrition, health and management. Therefore, knowledge on the reproductive phenomenon in goats and sheep is fundamental for effective management of flocks in order to promote overall meat productivity. Heterogeneous studies have applied a variety of indicators in evaluating reproductive rates in diverse flocks in the ranks are prolificacy, sexual maturity, age at first lambing, kidding/lambing interval, conception rates, kid/lambs weaned per year etc. (Ampong et al., 2019; Khandoker et al., 2018; Menatian et al., 2017; Getachew et al., 2015; Parajuli et al., 2014). Prolificacy, fertility and fecundity in goats and sheep are greatly dependent on breed, season, age, nutritional status, health, breeding management and production inputs (Deribe and Taye, 2014; Ali, 2006). Jahan et al. (2013) reported that amongst the non-genetic factors, nutrition and environment were the major determinants on reproductive performance of the fat-tailed sheep breed of Balochi. Due to its impact on economic viability (Hoque et al., 2002; Feng et al., 2011), prolificacy as a reproductive assessment parameter becomes more even significant determinant of efficiency of meat production in flocks (Haldar et al., 2014; Palai et al., 2013). Age at first kidding/lambing is an explanatory variable on small ruminant productivity as it turned out to influence lifetime reproductive performance (Schoeman et al., 1991). On the other hand, extended kidding/lambing interval has typically demonstrated to decrease overall productivity in African small ruminants (Wilson et al., 1985). The major contributor to total weight weaned per does is the number of young born alive per kidding hence an increase in total weight weaned per does will equally increase flock productivity (Feng et al., 2011). Genotype greatly influence prolificity in both goats and sheep, where in sheep prolificacy is associated with Booroola gene and as an example in goats, Jining Grey Chinese breed, have been regarded extraordinarily prolific (Feng et al., 2011). Due to the impact of heterosis and breed complementarity crossbreeding is an effective means of improving reproductive performances in ewes (Thomas, 2006; Fitch, 2012). A complete understanding of the indicators of reproduction and their management will assist goat and sheep producers to design management systems for the purpose of promoting reproduction and productivity. The purpose of the present review is to give an insight of some of the indicators of reproduction and how they can be managed for viability of goat and sheep enterprise.

2. Age at puberty/sexual maturity in goats and sheep

Most goats reach puberty at a relatively young age, however, there is considerable differences between genotypes. Puberty is the stage of sexual development where animals have the capacity to reproduce and onset of sexual activity. Sexual activities are associated with the production of the pituitary hormonal profiles, which result in enhanced size and activity of the gonads (Cupps, 1991). The major sexual hormones involved are testosterone and estrogen in males and females, respectively. Female cyclicity known as estrus is initiated preceded by ovarian activity and ovulation in female, while in males this is the start of sperm ejaculation (Snyman, 2010). In most cases age at first sexually competency is influenced by growth and body weight rather than age in tropical goats (Bushara and Abu-Nikhaila, 2012). Various factors have been implicated for the delay in age at first kidding such as genetics, climate and management practices (Khandoker et al., 2018). Onset of sexual activities appreciatively varies, aside from age dependency, in fact its influenced also by other factors like breed, nutrition, management, environmental temperature, photoperiod and body weight (Adam and Robinson, 1994; Delgadillo and Malpaux, 1996). A number of studies working with different goat breeds observed that puberty attainment was between 6-18 months, however this discrepancy was ascribable to differences in ecological and management conditions (Dereje et al., 2015; Baloch, 2014; Zarkawi and Al-Saker, 2013). Chemineau et al. (1991) prescribed the live weight between 40 and 60% of the adult body weight as the optimal age at puberty, while age at puberty was cited as attained at between 5 to 18 months in sheep and goats (Zeshamani et al., 2007; Delgadillo et al., 2007; Song et al., 2003). On body weight breeding at first sexual maturity could be extended until an animal attained 60-70% of its adult body weight (Greyling, 2010). Attainment of age of sexual maturity was slower in lowlands as compared with the highlands (Assen and Aklilu, 2012), however in the same context agro-ecological conditions did not influence age at puberty, however age at puberty was prominently shorter in highland (Hussein, 2018). In a similar study Mukasa and Lahlou (1995) observed that Menze sheep in central highland of Ethiopia attain puberty at 300 days at a weight of 16.9 kg which was 56% of mature body weight. Moaen-ud-Din et al. (2008) observed that nearly all goat breeds, attain sexual maturity at the ages between 6 to 8 months. However, the initial mating is dependent on growth than their age and goats are exploited at the age when they reach 60 to 70% of their mature body weight (Sodiq et al., 2003). This has been necessary because early exploitation of females will shorten generation interval therefore enhancing genetic progress. Kidding at the end of winter and in early spring, in different breeds, except the late-maturing Damascus and portion of the Anglo- Nubian, kidding for the first time was at the age of 1 year. In different circumstances reproductive efficiency of goats in their lifetime is increased by mating them early. Comprehensive reproductive efficiency of goats and sheep change considerably dependent on production environment. Goats and sheep reared under low input systems, especially associated with harsh environmental conditions, with inadequate feed resources and compromised animal husbandry practices, tend to experience poor fertility rates with reference to those reared under improved production systems. Seasonal variation has a bearing on reproductive traits in goats and sheep. Parajuli et al. (2014) observed that does bear from dams conceived during summer reach untimely sexual maturity and initial kidding in contrast to those that conceived in winter. The reason for this observation was that possibly does which conceived in the course of summer season take advantage of rather high quality fodder and forage which give rise to rapid and appropriate growth of conceptus. Tropical sheep breeds are not season dependent breeders unlike their temperate counterparts, however breeding can be manipulated in order to coincide with the most suitable time of the year through scheduling mating (Osinowo, 1982). Seasonal lambing summits have been accredited essentially to nutritional status associated to local variation in rainfall, vegetation, growth and availability of forage (Regassa at el., 2006). Reproduction demand almost the entire time comparable nutrients that are indispensable for maintenance, growth and milk secretion, hence properly balanced nutrition can impact positively on the reproductive soundness of the flock.

3. Age at first kidding/lambing in goats and sheep

Age at first birth, age at puberty, appropriate nutrition, breed and agro ecological region are important characteristics relevant to overall reproductive efficiency (Menatian et al., 2017). Song et al. (2006) reported the age of goats at first kidding in extensive and intensive rearing system of 412,1 and 382 days, respectively, while elsewhere Alexandre et al. (1999) reported 17,2 months as age at first kidding in Creole goat. Payne and Wilson (1999) reported that the average ages at first kidding in goats in the tropics vary between 12 to 18 months. However, this value was lower than the value reported by for Arsi Bale goats (Dadi et al., 2008). In a number of studies age at first kidding ranged from 387-693 days among diverse production conditions and goat breeds (Zarkawi and Abu-Saker, 2013; Lund, 2006; Ali, 2006; Sodiq, 2002; Song et al., 2003; Wilson, 1988). Adu et al. (1979) working with Red Sokoto goat of Nigeria observed that age at first kidding was 435 days, the average litter size at first kidding was 1·45 and prolificacy increased with advanced parity order, while the kidding proportion from first to third parities being 141, 186 and 200%, respectively. The age at first kidding/lambing signifies the age when ewes/does bear young ones for the first time. This is an indispensable index in ascertaining of sexual maturity and life time productivity in ewes/does. Deribe and Taye (2014) reported that the early the replacement females starts to give young ones, the more the young ones in their life time, and also the longer the productive life. Mukasa-Mugerwa and Lahlou-Kassi (1995) working with Menz sheep in the Ethiopian highlands observed that ewe lambs attain puberty (10 mos), first lamb (15 mo), postpartum anoestrus (76 d) and lambing interval (8.4 mo). Age at first lambing was not influenced by agro-ecological zones whereas age at first kidding of does was comparably extended in lowland with reference to midland and highland (Hussein, 2018). Warui et al. (2007) reported that delayed age at first kidding was associated with dry years, which signifies that the dams had an opportunity to develop to full body size prior to first kidding.

4. Kidding/lambing interval in goats and sheep

Lambing interval is a valuable indicator of reproductive efficiency in a flock (Ampong et al., 2019). The variation in interlambing period could be explained by differences in management practices and genotypes (Gbangboche et al., 2006; Tuah and Baah, 1985; Fall et al., 1982). The interkidding/lambing period is the period (in days) between two consecutive parturitions and is among the principal constituencies of reproductive performance that have an impact on productivity (Daribe and Taye, 2014). Shortest possible interkidding period of 3.84 to 8.5 months was observed for native Ethiopian goat breed (Netsanet et al., 2016; Belay and Greet, 2012; Jemal, 2008). Gbangboche et al. (2006) observed shorter lambing interval with advanced parity order of ewes in the Djallonké. This was ascribable to the fact that primiparous ewes are still growing hence may be competing with their foetuses for available nutrients for growth and development. This has a negative impact on the growing foeatus as a result the extended interlambing period. In a similar study sex of lamb, type of birth or parity of dam were not sources of variation on interlambing period (Ampong et al., 2019). Inadequate grazing land diminished the availability of feed resources for adequate dam nutrition resulting in body weight loss therefore lengthening lambing to conception and thus protracted lambing intervals (Ampong et al., 2019). London et al. (1994) observed that interlambing period imply protracted under controlled mating systems as compared to uncontrolled traditional breeding systems. However, extended duration of split of breeding males from breeding females is liable to prolonged lambing intervals. According to Jainudeen et al. (2000) interlambing period in excess of 243 days prohibit the choice of attaining three lamb crops in two years, which was proposed as the optimum production threshold for sheep in the tropics. Alexandre et al. (1999) reported interkidding period of 8,5 months in Creole goats, while Moaen-ud-Din et al. (2008) reported an extended interval range of 217 to 334 days in Chinese goat breeds which was parity dependent. Lactation could last only as long as kids are suckling, which makes the option of three kiddings in two years feasible, although the duration of lactation period from 240 to330 days, optimal kidding interval is 365 days. Ćinkulov et al. (2019) reported kidding interval in goats that varied within limits 222-498 days, in average 337 days. It has been noted that the period between two successive kiddings is a very crucial characteristic especially in fattening goat breeds. Dickson-Urdaneta et al. (2000) observed that kidding interval increased as years progressed, whereas prolificacy declined in the initial 4 years, subsequently commenced to increase. On the other hand, the breed effect was not important in kidding interval thereby Alpine averaging 390.7 against 414.4 days for Nubian. Morlam and Carnal Dorset ewes, experienced average lambing intervals of 293 and 303 d, respectively. However, lambing intervals of Morlam ewes where extended when mated at early ages of less than a year and when the preceding lambing occurred in winter (Iniguez et al., 1986). Bilal et al. (2018) working on reproductive traits (age at first heat, age at first kidding, kidding interval, service period, number of services per conception and twinning percentage) in ten goat breeds of Sindh, observed that age at first heat was lowest in Pateri (around 7 months) whereas the rest of the breeds ranged from 11 to 15 months). The maximum twining percentage at first kidding was 25% in Chappar, whereas the Jattan had lowermost kidding interval at 5 months. The average kidding interval for the long legged West African goat in pastoral system was reported as 328 days (10.9 months) (Wilson, 1991). Several authors working with Awassi crossbreds' ewes suggested that the inferiority in age at first lambing and lambing interval might not a problem because they are most likely to be compensated by the relative larger size of ewes prompted in enhanced capacity for crossbred ewes to raise their lambs to weaning age (Tibbo, 2006; Getachew et al., 2015).

5. Prolificacy/litter size in goats and sheep

Martyniuk (2009) reported that Olkuska sheep had outstanding prolificacy and good maternal traits. Characteristically with single lambing per year, the average litter size of two and over two years old ewes is at a minimum of two (IZ-PIB, 2005). That kind of superior prolificacy had a genetic basis influenced by a single gene of a major effect enhancing ovulation rate in carriers. Breed and year of kidding greatly influenced prolificacy where Alpine and Nubians had a mean of 1.25 and 1.38 kids per parturition, accordingly (Dickson-Urdaneta et al., 2000). Due to its impact on economic viability (Hoque et al., 2002; Feng et al., 2011), prolificacy as a reproductive assessment parameter becomes more even significant determinant of efficiency of meat production in flocks (Haldar et al., 2014; Palai et al., 2013). The major contributor to total weight weaned per does is the number of young born alive per kidding hence an increase in total weight weaned per does will equally increase flock productivity (Feng et al., 2011). Measures for assessing prolificacy improved under selection these include increased ewe fertility, increased ewe ovulation rate and increased ewe litter size (Bhuiyan and Curran, 1995). In goat several authors reported comparatively average prolificacy of 1.43, 1.41, 1.45, 1.49, 1.51 in Transmontano ecotype Serrana in Spain (Margatho et al., 2019), Nubian breed in India (Jan and Gupta, 1981), Alpine breed in Egypt (Mourad, 1993), crossbred dairy goat in Brazil (Sarmento et al., 2010) and Florida breed in Spain (Morantes, 2012), respectively. However, a lower prolificacy of 1.38 was also reported by Dickson-Urdaneta et al. (2000) in Nubian does. Sacoto and Simões (2016) observed that prolificacy of the Serrana goats was greatly influenced by parity, reaching its maximum around the 5th kidding. In similar studies year of kidding was implicated as the major explanatory variable for prolificacy in goats (Dickson-Urdaneta et al., 2000). Prolificacy in Portuguese Serrana goats was that it decreased from the months of December onwards and up until April, as a result monthly variation highly influenced prolificacy (Odubote, 1996). Đuričić et al. (2012) reported in Boer goats the prolificacy rate of 180%, this was lower compared with the same breed in Botswana, South Africa and US which experienced at 193.42% (Seabo et al., 1994), 189% (Malan, 2000) and 185% (Browning et al., 2006), respectively. Breed selection can greatly influence reproductive performance, especially prolificacy and age at first lambing. Maternal breed lines should be bred for possessing good maternal ability, prolificacy, nonexistent reproductive seasonality and good adaptation especially for those to be used in tropical environment (McManus et al., 2014; Issakowicz et al., 2016). Turkyilmaz and Esenbuga (2019) Cross-breeding Turkish indigenous Morkaraman ewes with prolific Romanov rams on the reproduction performance of the crossbred offspring under semi-intensive production systems. Crossbreds displayed inferior performance for age at first lambing, lambing interval, and number of lambs born per ewe per year as compared with indigenous breeds in various locations. However, crossbred and indigenous ewes were comparable in number of lambs weaned per ewe per year (Getachew et al., 2016). Gootwine (2016) reported that in Finn sheep, Romanov and East Friesian sheep breeds high prolificacy is multilocus trait or a single autosomal trait or X-linked major gene, as has been identified in Booroola Merino and Inverdale genes, respectively. Baluchi sheep of Iran has fertility, prolificacy and twinning rates of 92.67, 101.33 and 10.14%, and age at first service, age at first lambing service period, and lambing interval of 579.61±0.60, 731.67±0.30, 206.25±0.20 and 256.60±0.30 days, respectively (Jahan et al., 2013). Fertility and prolificacy percentages of ±1.3 and Karakul 99.2 100.4±2.6, Mehraban 99.0±1.3 and 108.5±2.7 (Farid et al., 1989), Chall sheep 77.34 and 111.34, Moghani 84.64 and 110.45, Zel 94.37 and 113.77 have been reported (Kiyanzad et al., 2003) and for Naeemi (88±20 and 139±2.0 Razzaque and Mohammed, 2010). Matika et al. (2003) reported that prolificacy was the only reproductive trait of the Sabi sheep where reasonable genetic progress is possible through selection. However, this should be carefully considered in view of the low survival rate among twin-born lambs. The low heritability estimates of lamb survival may indicate that higher survival rates could better be achieved through a better control of the environmental factors.

Alexandre et al. (1999) defines litter size or number of kids in the litter as a total number of born kids per kidding and per ewe. Litter size is greatly influenced by age and parity (Amoah and Gelaye, 1990), however, Awemu et al. (1999) observed that in addition to parity, litter size could be influenced by year and season. Litter size is expressed as a total number of born kids/lambs per kidding/lambing per ewe/doe. The litter size is a preferred trait for selection in small ruminants to decide the parents of the next generation and enhance dams milk production. A number of studies have assessed the association between litter size and survival of lambs in various prolific sheep breeds (Gootwine et al., 2008; Kleemann and Walker, 2005; Fogarty et al., 2000). Khandoker et al. (2018) working with Saanen dairy goat, observed that litter size increases with advanced dam age. On the other hand, ewe productivity, prolificacy and number of lambs weaned were enhanced with increases with the ewe's age (Dawson and Carson, 2002). There has been inconsistence of the number of kids per doe in goats in different studies, for example the average number of kids per doe was 1.77 in Nubian goats in Mexico (Mellado et al., 1991) as compared to 2.3 to 2.9, 1.94, 1.89 and 1.7 to 2.4 kids in Egypt (Marai et al., 2002), Spanish goat in the US, Kiko (Browning et al., 2006) and Creole goats of Guadeloupe (Alexander et al., 1999), respectively. Ćinkulov et al. (2019) reported litter size of 1,96 kids, which was within the lower rage of values reported elsewhere for goats of different breeds; (1,85 kids - Amoah et al. (1996); 2,06 kids - Sodiq et al. (2003); 2,09 kids - Moaen-ud-Din et al. (2008). The differentiated values may be due to differences in parities where first and second kidding, when litter size is smaller with reference to later kiddings. The explanation of the variation could possibly be due to genetics of breeds, also not ignoring the influence of variation in production environment, especially nutritional regime and general management. Kandiwa et al. (2020) working with sheep and goats observed that litter size was influenced by genotype, while twinning was more constant in Dorper sheep, Kalahari Red and Boer goats as against the Damara and Swakara sheep. Similarly, triplets were more popular in the Dorper sheep and Kalahari Red goats. The determinants of litter size are varied, Amoah and Gelaye (1990) reported that age and parity, influenced litter size while, Awemu et al. (1999) included year and season as greatly influencing goat litter size. Parity influences litter size, Josh et al. (2018) reported parity dependent reproductive performance in goats, where reproductive efficiency was associated with specific parities. In a similar study, Sapkota et al. (2012) observed that the far most productive parity order for Khari x Jamunapari crossbreds was from third parity to fifth parity. This was ascribable to goat kids born of middle parity had maximum body weight as a consequence of extensively developed reproductive system. The attained high weight gain in middle parity was also associated with high rate of ovulation as a result of the well-developed reproductive system. Warui et al. (2007) reported that the reduced litter size experienced in two goat populations was attributable to reduced twinning rate as a result of adverse environmental conditions and also the calculated selection for single births by culling does that kid twins at initial birth In a similar study, Mukasa-Mugerwa and Lahlou-Kassi (1995) reported that litter size (prolificacy) of 1.12 had a potential to be elevated to 10–40% as a result of premating ewe nutrition management or administration with gonadotropins. Davis et al. (1983) observed that as the average litter size excelled above 1.7, the downturn in single-bearing ewes is counterbalanced by an enhancement in triplet-bearing ewes. Adequate milk production at this stage will sustain lambs because their development is mainly dependent on the milk of the dam. Weaning and market weight as measures of reproductive performance were superior in Dorper sheep against indigenous sheep breed of Adilo, however, comparable in sexual maturity and litter size (Belete et al., 2015). Olsson and Beyene (1990) observed that total weaning weight of crossbred lambs per ewe born was improved with proportionate increase in exotic genes, while litter weight and lamb survival was comparable. Superiority in litter size was experienced during hot dry season as compared to other seasons. This was explained be abundant feed resources availability during conception in wet season. Good nutrition at mating season enhances body condition and females body weight as a result improving ovulation and high chances' of fertilization (Bushara et al., 2013; Dadi et al., 2008; Mellado et al., 2006).

6. Implication

- ✓ The viability of any goat and sheep enterprise is dependent on various interrelated factors (genotype and non-genetic) that promote reproductive performance as they influence on the number of kids/lambs born, reared, weaned and then marketed annually.
- ✓ Reproductive characteristics are sensitive to environmental consequences, hence can positively adapt to sound flock reproductive management practices. More or less important variables which goat and sheep farmers need to give attention in order to enhance reproductive performance are age of animal, weather and seasonal variation and nutritional status. Sound animal husbandry practices can mitigate reproductive losses consequently improving the overall meat production.

✓ Regardless of the fact that genetics is a critical component in influencing reproductive capacity in goats and sheep meat production, reproductive traits are lowly heritable as a result any attempt to genetically improve reproductive efficiency becomes slow and difficult. This means enhancing reproductive efficiency through genetic selection is completely implausible.

✓ Due to the impact of heterosis and breed complementarity, systematic crossbreeding is an effective means of improving reproductive performances in ewes/does.

✓ Age at first kidding/lambing is an important reproductive parameter as it influences lifetime reproductive performance in ewes/does.

✓ Prolificity, fertility and fecundity in goats and sheep are greatly dependent on genotype, year/season, age, nutritional situation, animal health and breeding management. An extended kidding/lambing interval will reduce overall productivity in goats and sheep meat production.

✓ Optimal nutritional status of breeding ewes/does will positively influence their reproductive performance; producers can manipulate nutrition through increasing nutrient consumption in order to promote reproductive parameters. Thus alleviation of seasonal nutritional stress in ewes/does would consequently enhance the annual reproductive rate of individual dams and overall flock productivity.

✓ An uninterrupted assessment of reproductive indicators throughout all phases in the reproductive cycle allows to adopt husbandry management practices that are meant to optimise reproductivity translating to overall meat production.

✓ Reproductive performance would greatly contribute to improved meat production efficiency as a result the understanding of this phenomenon in goats and sheep is fundamental for effective management of flocks in order to promote overall meat productivity.

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