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Reproduction in female yaks (*Bos grunniens*) and opportunities for improvement

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Abstract

This paper reviews seasonal breeding, puberty, postpartum anestrus, embryonic loss and calf survival and their constraints in female yaks. Methods for improving fertility in postpartum yak cows are also considered. Yaks are seasonal breeders with mating and conception restricted in the warm season. Puberty generally occurs in the 2nd to the 4th warm season following birth, i.e. between 13 and 36 months of age. The cows usually have a long postpartum anestrus period; only a small proportion of the cows return to estrus in the 1st breeding season after calving, most come into estrus in the 2nd and 3rd years. Nutritional status is the most important determinant of reproduction in female yaks. Reproductive success is a direct result of the availability of pasture determined by climate, season, and management practices. Milking delays puberty by reducing milk intake (restricted suckling) and growth rate for the calf. Milking interferes with grazing and prolongs the duration of postpartum acyclicity in cows. Calves born early in the season have a longer suckling season than those born later in the season before the onset of winter. Thus, they can have their first cycle in the breeding season of the following year, while those born late in the season may not have their first estrus until 25 or 26 months of age. Cows calving early in the season are more likely to return to estrus in the year of calving because they have a longer period to recover from the demand on body reserves before the onset of winter.

Inbreeding in smallholder yak farms is also discussed and minimizing inbreeding by exchanging bulls among different herds is suggested. Reproductive efficiency can be improved by nutritional supplementation during the winter, however, the most cost-effective and practical strategy for this needs to be determined. Early weaning or restricted suckling may shorten the duration of postpartum acyclicity, however, it is impractical due to reduced growth rates and increased winter mortality of early weaned calves. A single treatment with either GnRH, or $PGF_{2\alpha}$ + GnRH can successfully induce estrus in yak cows that calved in previous years (with or without calf) but did not calve in the current year, however, it has little effect in cows nursing a calf born in the current year. The effects of

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administration of exogenous progestogens plus GnRH on the fertility of yak cows are worthy of further study.

Keywords: Yak; Reproduction; Nutrition; Estrus induction

1. Introduction

The yak (*Bos grunniens*) is one of the world's most remarkable domestic animals—a herbivore living on the ''roof of the world'', in and around the Himalayas and north, in areas of altitude ranging from 2500 to 5500 m with no absolutely frost-free periods, and mostly above the tree line. Yaks provide food (meat and milk), transport, shelter (hair) and fuel where few other animals will survive. Thus, yak production fills an important niche in Tibetan life and in developing the prosperity of the people in the vast mountainous regions. The yak has a gestation period of 250–260 days which, theoretically, allows one calving each year. However, at present, its breeding is invariably once every 2 years or twice in 3 years [1,2]. Low reproductive rate is an important factor constraining yak production.

This paper reviews the published research work on reproduction in yaks and discusses methods for improving the reproductive efficiency of the yak.

2. Seasonal breeding

Like sheep in the temperate latitudes, yaks are seasonal breeders. The breeding season is restricted to the warm season (June to November), and the largest proportion of yak cows come into estrus in the middle of this period (July and August) in most yak production areas [1–12]. At the higher elevation of Shiqu County of Sichuan and Laqu County of Tibet (altitude >4500 m) the breeding season may not start until July as grass starts to grow later [4,7]. Similarly, the breeding season for the yak in Kirgiz varies with altitude. In the Tyan Shan, at elevations of 2400–2500 m mating starts in late June (sometimes earlier) and continues to late October (but occasionally into January). In the Altai valley with severer conditions, and an altitude of 3000–4000 m, mating does not begin until mid-July and ends in mid-October [12]. Yak females that calved in previous years but not in the current year come into estrus early in the season (June to August), but those have calved early in the season (before June) may come into estrus later in the year of calving (September to November) if they are in good body condition before and postpartum [7,13,14]. At Longrang farm of Hongyuan County of Sichuan, only 23.8% of initial estrus in the breeding season occurs in June and July, with the majority commencing in August; however, at the same elevation (around 3500 m) of Longrang farm of the county, where grass starts to grow earlier because of higher temperature and humidity, 49.2% of initial estrus in the breeding season occurs in June and July (Zi, 2000, unpublished data). After August, as air temperature falls, the nutritive value declines as the grass goes to seed and then wilts. Thereafter, yak estrus decreases in frequency and stops around November. However, yaks kept in some zoological parks, such as Whipsnade Wild Animal Park, do not show obvious seasonality, possibly due to lack of seasonal variation in food supply [1]. The physiology of this seasonal breeding is

rather poorly understood, but the evidence supports the theory that seasonal breeding in the yak is determined more by nutritional status and dietary nutrition level than by photoperiodic sensitivity of the hypothalamic–pituitary axis.

3. Puberty

First estrus generally occurs in the second to the fourth-warm season following birth, i.e. at ages between 13 and 36 months in yak production areas [1,3–7,9–12,15–18]. It is highly variable and is dependent on a number of factors.

Nutritional status and the rate of liveweight gain are important determinants of the time of onset of puberty, that is, faster growing yak heifers reach puberty at a younger age [1,17,19,20]. Zi et al. [20] weighed 1033 Jiulong yaks aged from 1 to 3 years and found that 93.1% of 2- to 3-year-old animals with body weights of 180–240 kg (60–80% of their mature weight) would enter puberty, but those with a slow growth rate during the prepuberal period did not start cyclic activity until they were 48–54 months old. Calves with dams that are also milked grow less well because the calves have a much shorter period of suckling and reach puberty later in the year than those calves which have exclusive access to the milk of their dams [12,19,21]. Nutritional supplementation during winter can significantly increase growth rate and hence advance puberty [22].

Season of birth also has a significant effect on the age at which puberty occurs. Evidence indicates that calves born from March to the beginning of May can have their first cycle in the breeding season of the following year (i.e. at 15 or 16 months of age), while those born late in the season may not have their first estrus until 25 or 26 months of age [3,6,11]. This is due to the fact that calves born early in the season have a longer suckling season before the onset of winter than those born later in the season.

It appears that age of onset of puberty differs among different breeds, but there is no direct comparison of breeds in the literature. Zi et al. [20] reported that Jiulong yak have a faster growth rate than other breeds of yak, but it seems that onset of puberty occurs at a time similar to other breeds in China and possibly later than in yaks of other countries [6,11,12]. This might suggest that there is less correlation between growth rate and puberty in yaks than in other domestic animal species. The variation in timing of puberty among different breeds is likely to result from their different genetic backgrounds.

4. Postpartum anestrus

The annual reproductive rate of most yak breeds is 40–60% [1,3,5,7,9,11,15,16,23,24]. Yak herd fertility is mainly determined by the proportion of yak cows returning to estrus in the year of calving since they are seasonal breeders and evidence shows their conception rate following natural service is high. In a study in Sichuan, 78% of female yaks were pregnant after a first service, 15% conceived after a second and 7% after a third or more [13]. There are similar reports from Mongolia [24] and Qinghai [25].

However, only a small proportion of the cows return to estrus in the 1st breeding season after calving; most come into estrus in the 2nd and 3rd years under traditional management

systems. For example, in Ruoergai County of Sichuan, 14.3% of yak cows return to estrus in the year of calving, 59.6% in the 2nd year and 13.9% in the 3rd year [13]. Similar observations are reported from Qinghai and Gansu [7,26]. Thus, yak females are most likely to calve once every 2 years or twice in 3 years. There might be genetic variation within and between different breeds, but pre- and postpartum body condition appears to be an important determinant [9,14,24,27]. Postpartum anestrus periods are found to be much shorter (70.5 ± 18.5 days) for yaks in good body condition prepartum than for those in poorer body condition (122.3 ± 11.8 days) [14]. Yak cows have a calving rate of 71.0% under a once daily milking system compared with that of 51.4% under a twice daily milking system [27]. In the latter system, cows have a longer period of grazing daily near the campsite resulting in over-grazing and poor quality pasture, and a shorter grazing period on alpine pasture, therefore, milking affects postpartum anestrus mediated by nutrition. Furthermore, those yaks calving in the early part of the season (March, April and May) are more likely to return to estrus in the year of calving [3,7,12,24,26], because they have a longer period to recover from the demand on their body reserves.

It appears that suckling effect rather than lactation per se has the stronger influence on the postpartum anestrus period, as evidence shows that cows are more likely to return to estrus in the 1st breeding season after calving if their calves are slaughtered or die in early life [19,28]. Age has also been recognized as an important factor; cows aged 5–13 years usually have a shorter period of postpartum anestrus [11,16,28].

5. Prenatal and postnatal calf survival

It is widely accepted that abortion and other causes of premature termination of pregnancies account for 5–10% of all pregnancies [1,4,7], however, data based on observation of abortion is in question because the number of pregnant yaks is usually not accurately diagnosed. Embryonic loss depends mainly on the level of nutrition and environmental conditions.

In Hongyuan County of Sichuan, supplementation of yak cows diets with hay from mid-December to the end of April (the latter part of pregnancy) was shown to have a small effect on the number of calves born [29], but in Gansu and Qinghai, the calving rate of female yaks whose diet was supplemented with oat hay in the cold season reached 74.6% compared to 53.7% in controls [27]. This indicates a high rate of embryonic loss caused by malnutrition in the latter situation. The abortion rate is also greatly increased by starvation caused by exceptionally heavy snow in the winter. For example, 43.5% of 2567 pregnant yak cows aborted in the snow disaster of 1995–1996 that occurred in Shiqu county of Sichuan (Zi, 1997, unpublished data).

Calf survival rate is variable and is dependent on a number of factors. A 90% survival rate is not unusual when the calves are allowed to suckle and the dams are not milked or are milked once daily [1,4,7,15,18,21], but can fall greatly when the cows are milked twice daily, possibly due to a consequence of difference in milk intake by the calf. When the dam is milked only once daily the calf is kept apart from the dam for 9–12 h every day (usually during the night) and grazes alongside the dam for most of the day. However, calves with dams milked twice a day have perhaps only 4–5 h during which they move around at pasture

with their dams. A survival rate of 93.7% (1932/2061) in cows not milked compared to that of 57.9% (522/902) in cows milked has been observed [21]. Like other domestic animal species, calves with high birth weights have a higher survival rate compared with low birth weight calves [30,31], and body condition of the dams during pregnancy also affects calf survival through its effect on birth weight [14,29]. Month of calving is also an important factor affecting calf survival. Calves born from April to June have a higher survival rate; those born out of these months may suffer from either extreme cold weather and malnutrition at calving, or low body weight before the onset of the first winter of their life [4,28,32].

6. Methods for improving reproduction in yak females

6.1. Strategic supplementation in the winter

In Hongyuan County of Sichuan, supplementation with hay (the indigenous grass species) plus urea in the cold season from December to April gave little benefit in terms of improving fertility in adult females. Food intake in late winter is only 1/3 of that in the warm season, and it cannot be greatly increased by supplementation with hay alone [29]. This suggests that nutrients in hay are too low to maintain the normal function of the rumen, and the level of energy and protein in supplemented food must be considered. In another study, female yaks fed a formulated feed and hay in shelters during the cold season and grazed on pasture in the warm season reached puberty earlier, and all cows returned to estrus and conceived in the 1st breeding season after calving [22]. In a well-designed trial conducted in Qinghai and Gansu, the diet of yak cows is supplemented with oat hay or barley straw of the local agricultural by-products in the winter. Their calving rate greatly improved; 74.6% calved compared to 53.7% in the control group. Eighty percent of cows in the supplemented group started cyclic activity within 40 days as judged by changes in progesterone concentration in milk, while only 50% of control cows commenced cyclic activity in the same period [27]. Consequently, in the following summer, 73.0% of supplemented cows conceived compared to 54.8% in the control group [33].

It is clear that the shortage of available pasture during the cold season is the most important constraint to reproductive efficiency, and nutritional supplementation during the winter can improve fertility in yak cows. However, question such as cost-effectiveness, nutritional requirements and appropriate feeds must be addressed. In beef cows (*Bos taurus*), increasing energy intake beginning 2 months before parturition shortens the postpartum interval to estrus. Increasing energy intake beginning at 2 weeks before parturition, beginning at parturition or beginning at 4 weeks after parturition increases the number of follicles [34]. Obviously, nutritional supplementation strategies for yak cows need to be further studied and knowledge acquired from studies in cattle would be an appropriate source of information.

6.2. Weaning

Yak cows whose calves died soon after birth or non-suckled cows are more likely to return to estrus in the year of calving. In Qinghai and Gansu of China, where large numbers

of calves are slaughtered during the period from the end of September to the beginning of October for commercial use, a large proportion of yak cows return to estrus and pregnancy within 7–21 days [19,28]. It appears that suckling effect rather than lactation per se has the stronger influence on the postpartum anestrus period, as in other animal species [34–37]. Early weaning or restricted suckling may shorten the postpartum anestrus period, however, complete, temporary or partial weaning require changes in management and increased labor, and result in reduced growth rate and increased winter mortality of weaned calves, all of which make early weaning impractical for yak holders. However, in current practice it is not unusual that calves are allowed to suckle and graze alongside their dams until the second warm season of their life if their dams do not calve again. Weaning must be emphasized in such a situation.

7. Induction of estrus in postpartum yak cows

7.1. GnRH

A single administration of 250–350 μg of LRH (analogue of GnRH) induced a rise in serum LH concentration [38] and ovulation in breeding season, and pregnancy rates at the end of breeding season were greatly improved in yak cows that calved in previous years (with or without calf) but not in the current year [39–42]. However, this response is variable and the variability is difficult to explain in yak cows nursing a calf born in the current year. In a recent study, 20 yak cows of the latter category were treated with 300 μg of LRH. In the calving season of the following year, a calving rate of 8/10 was achieved compared with 8/26 for controls in one herd, but in another herd these rates were 2/10 and 4/16, respectively [38]. However, it is widely accepted that the pregnancy rates of yak cows of breeding age can be increased by 10–20% if treated with LRH in the breeding season. In cattle, GnRH-induced corpora lutea (CL) usually have a shorter lifespan than spontaneously formed CL [43–45].

7.2. Treatment with triple hormones

In China, triple hormones (a mixture of androgen, progesterone and estrogen) were commonly used to induce estrus in the 1980s. After treatment with triple hormones, usually more than 90% of yak cows began estrus and ovulated within 6 days. However, conception rate was variably low, and there was little benefit in terms of calving rate [40,41,46].

7.3. Prostaglandin with other treatment

Estrus can be induced by administration of prostaglandin ($PGF_{2\alpha}$). In one study the rates of induced estrus following a single administration of $PGF_{2\alpha}$, were 57.5% compared to 30.0% for controls, but the conception rates of the induced estrus were lower compared to the controls (56.5% versus 75.0%) [47]. In another study, administration of $PGF_{2\alpha}$ + LRH to yak cows that calved in the previous year (with or without calf), resulted in 89.5% (17/19) of the cows ovulating within 7 days after treatment; 73.7% (14/17) of cows treated

become pregnant in the following two breeding cycles compared to 38.9% of control cows. However, employing the same method for yak cows nursing a calf born in the current year, only 7% of cows ovulated and became pregnant within two breeding cycles [41]. These results are similar to the findings in postpartum suckled beef cows [48], i.e. $PGF_{2\alpha}$ + GnRH can induce ovulation following normal pregnancy rates in cyclic cows, but do not work well in anestrus, postpartum cows. In cattle, evidence also shows that most of the luteal phases that follow ovulation induced by $PGF_{2\alpha}$ + GnRH treatment are 6–12 days [45]. When cows have been bred at an estrus with an expected subsequent short luteal phase, conception may occur but pregnancy is generally not maintained. Norgestomet treatment before early weaning and GnRH treatment, however, has reduced the incidence of short luteal phases and improved pregnancy rates in acyclic cows [44,48]. Recently, progesterone releasing devices and implants have been developed and their use in cattle demonstrates that they have some advantages in simple application and reasonable results over than the traditional methods of injections. There is no reason why these approaches should not be evaluated in the yak.

8. Genetic options

8.1. Genetic selection

Reproduction is likely to have a low heritability, but its improvement by genetic selection must be considered in the long term. This might be estimated by a cow's total calf production by 5 years of age as suggested by Wiener [49]. This would place emphasis on early first calving and regular calving thereafter.

8.2. Minimizing inbreeding

Smallholder yak farms usually choose a single sire from their own herd and keep it in use for many years. The sire is commonly still in use in the herd after his own daughters have reached mating age. Also it is not uncommon in a herd, when choosing a replacement for a bull, to use a son or other close relative of the bull in the same herd. Thus, inbreeding is not uncommon in smallholder yak farms in some countries, such as Bhutan, Nepal, India and China [1,50,51]. It is reported that when the inbreeding coefficient increases from 0 to 0.108, calving rate will decrease from 56.7 to 43.0%. When the inbreeding coefficient increases from 0 to 0.125, calf survival will decrease from 93.5 to 66.7% [50]. This shows the harmful effects of inbreeding on reproduction rate and calf survival, therefore, minimizing inbreeding simply by exchanging yak bulls among different herds would improve yak reproduction.

9. Conclusion

Reproduction in yaks is low as a result of seasonal breeding, delayed puberty and lower frequency of estrus. These effects are amplified by shortage of pasture food during winter

and management practices. Nutritional supplementation during winter is strongly recommended since it can improve calf survival, advance the age of puberty, increase calving rate by reducing embryonic loss, and increase the proportion of cows returning to estrus in the following breeding season by a carry-over effect. However, determination of the most cost-effective and practical strategy needs to occur. Milking has a harmful effect on fertility and calf survival as a result of shortening the period of grazing for cows, and suckling for calves, respectively. Early weaning is impractical, but calves should not be allowed to suckle their dams at their second warm season after birth. Inbreeding must be recognized as a problem in current practice where, in relatively small herds, a bull is usually replaced by his sons or other closely related animals.

Breeding cyclic cows and inducing estrus with a single treatment of $PGF_{2\alpha}$ + LRH, in cows that calved in previous years (with or without calf) but have not been bred during the early breeding season (e.g. June and July) will advance the calving season, and more cows would be expected to spontaneously return to estrus during the breeding season of the following year. Insertion of progesterone releasing devices or implants into any cows that have not been bred at the end of breeding season (e.g. at the end of August) along with GnRH at the time of withdrawal plus a single treatment with GnRH at 48 h after withdrawal is suggested.

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