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Research Article

KLEIBER RATIO IN SIROHI GOATS

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ABSTRACT

To estimate the pre and post weaning Kleiber ratios (KR) and the factors influencing them, data from 6,748 Sirohi goats in farmers' flocks were analyzed. The overall least-squares means for the Kleiber ratio from birth to three months (KR1) and from three months to twelve months (KR2) were 16.26 ± 0.06 and 4.11 ± 0.03 gm/kg of metabolic weight, respectively. The study examined the effects of sire, period, season of birth, sex of the kid, type of birth, cluster, and parity on the Kleiber ratios. Among these factors, the sire was treated as a random effect, while all others were considered fixed effects. The results indicated significant effect ($P \leq 0.05$) of all the factors on both KR1 and KR2. Heritability estimates for KR1 and KR2 were 0.65 ± 0.07 and 0.29 ± 0.05, respectively. The genetic and phenotypic correlations between KR1 and KR2 were found to be high but negative.

Keywords: Genetic correlation, Heritability, Kleiber ratio, Least-squares means, Sire, Sirohi goat, Phenotypic correlation

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Among the 41 registered goat breeds across India's diverse agro-climatic zones, the Sirohi goat holds a prestigious status due to its superior qualities, such as faster growth rates, lower disease incidences, and enhanced adaptability to dry, hot climates. The breed is predominantly found in the regions surrounding the Aravali hills in Rajasthan, particularly in the districts of Sirohi, Udaipur, Rajsamand, Pratapgarh, Chittorgarh, Nagaur and Ajmer. Additionally, its popularity has led to the expansion of its home tract into other adjoining areas also. The importance of goats in the Indian meat industry is undeniable. As a meat animal, fast growth and efficient feed conversion are key economic traits. In India, where most goat flocks are reared under extensive or semi-intensive systems, traditional metabolic trials are often not feasible for assessing feed conversion efficiency in free-range grazing conditions.

The Kleiber ratio (KR), defined as growth rate/body weight$^{0.75}$ (Kleiber, 1947), provides an indirect but reliable criterion to evaluate feed conversion efficiency. This ratio is independent of body size and does not require individual intake measurements, making it especially useful for free-range animals. Goats with a higher KR require less maintenance energy, thereby demonstrating a more efficient use of feed. (Vyas *et al.*, 2024) However, studies on the Kleiber ratio in Sirohi goats are scarce. To address this gap, the present study was undertaken to identify the factors influencing the Kleiber ratio and to estimate both the genetic and phenotypic parameters associated with this trait in Sirohi goats under field condition.

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MATERIALS AND METHODS

The data used for this study were collected from Sirohi kids born between 2005 and 2017 in farmers' flocks registered under the All India Coordinated Research Project (AICRP) on Goats (Sirohi Field Unit), Livestock Research Station (LRS), Vallabhnagar, Udaipur. As per the technical protocol of the project, all registered animals were properly identified through ear tagging. Vaccination and deworming were carried out according to established guidelines, ensuring the health and welfare of the goats. To improve the genetic quality of the flock, elite Sirohi bucks were provided to farmers for breeding. The farming system predominantly followed a semi-intensive management approach, where goats were allowed to graze for 8-10 hours a day, while they were housed at night. The goats primarily fed on natural vegetation, including shrubs such as Ber (*Ziziphus mauritiana*), Ker (*Capparis decidua*) and Thor (*Euphorbia caducifolia*), as well as trees like Neem (*Azadirachta indica*), Khejri (*Prosopis cineneraria*) and Ardu (*Ailanthus excelsa*). Kids were weaned at 3 months of age.

Kleiber ratio from birth to three months age (KR1) and from three months to twelve months age (KR2) were calculated as following formulae:

KR1 = ADG from 0-3M in gms. /Metabolic weight at 3M age (3 MBWT$^{0.75}$) in Kg.

KR2 = ADG from 3-12M in gms. /Metabolic weight at 12M age (12 MBWT$^{0.75}$) in Kg.

As the data were non-orthogonal, analysis was performed to estimate the least-squares means and genetic parameters through Mixed Model Least-Squares and

Maximum Likelihood method designed by Harvey (1990). Duncan's Multiple Range Test as modified by Kramer (1957) was used to make pairwise comparison among the least squares means.

Effect of sire, period, season of birth, sex of kid, type of birth, cluster and parity were studied on Kleiber ratios. Among these, sire was considered as random effect whereas all others were as fixed effects. Year of birth was categorized into 3 periods: P1 (2005-2009), P2 (2010-2013) and P3 (2014-2017). Season of birth was classified into three categories i.e. rainy (July-October), winter (November-February) and summer (March-June). Sex was grouped as male and female whereas type of birth was categorized as single and multiples. Data were collected from six clusters that were Vallabhnagar (Udaipur), Railmagra (Rajasamand), Deogarh (Rajasamand), Nathdwara (Rajasamand), Bhadsoda (Chittaugarh), Karget (Udaipur), Bojunda (Chittaugarh) and Salumber (Salumber). Parity of dam was classified as first to fifth. Kids born in above fifth parity were pooled into 5th parity group.

RESULTS AND DISCUSSIONS

The overall least-squares means for KR1 (0-3M) and KR2 (3-12M) were 16.38±0.03 and 4.11±0.05, respectively which has shown in table 1. Higher Kleiber ratio from birth to three months age depicts the better feed conversion efficiency during pre-weaning stage which occurs due to suckling of dam's which serves as a complete nutritious food for kid. Similar performance for KR1 was observed by Barazandeh *et al.* (2012) as 15 and Mokhtari *et al.* (2019) as 15.27 in Raieni cashmere goats, Khadda *et al.* (2018) as 15.29±0.16 in Pantja goats and Thepparat *et al.* (2012) as 14.82 to 18.00 in mixed population of goats. However, the finding of KR1 in Sirohi goats was found closer to the sheep rather than goats as per available publications. KR1 was recorded by Ved Praksah *et al.* (2012a) as 16.88±0.06 in Malpura sheep, Mandal *et al.* (2015) as 16.18±0.06 in Muzaffarnagari sheep, Kumar *et al.* (2017) as 15.44±0.14 and Banger *et al.* (2018) as 16.47±0.05 in Deccani sheep, Kumar *et al.* (2018) as 15.86±0.07 in Nellore Jodipi sheep and Illa *et al.* (2019) as 16.00 in Nellore sheep. Regarding KR1, more similarity of Sirohi goats towards sheep breeds indicates its better feed conversion efficiency. Lower estimates for KR1 was reported by Vyas *et al.* (2024) as 12.89±0.03 in Marwari goats, Tesema *et al.* (2020) as 13.99±0.11 in Boer x Central Highland goat, Rashidi *et al.* (2011) as 14.1 in Markhoz goats for 0-4M age, Supakorn and Pralomkarn (2012) as 10.26±1.31 in crossbred goats for 0-5M age, Nakavisut and Thepparat (2014) in Thai native goats as 14.72, Gupta *et al.* (2016) as 14.20±0.13 in Mehsana goats and Dige *et al.* (2021) as 13.74±0.02 in Jamunapari goats. Thus, the highest value of KR1 in Sirohi goats among all the Indian goat breeds so far reported proves its supreme status regarding feed efficiency during pre-weaning stage. Regarding KR2, lower estimate was reported by Kesbi and Gholizadeh (2017) as 3.307 in Baluchi sheep.

Highly significant effect (P≤0.01) of sire was found on KR1 and KR2. Similar results were found by Khadda *et al.* (2018) in Pantja goats. The significant effect of sire on Kleiber ratio indicates the existence of additive genetic variability among these traits.

Period of birth also had highly significant effect (P≤0.01) on both Kleiber ratios. For both Kleiber ratios, significantly higher value was reported during second period (2010-2013). The difference in performance for KR over the years might be due to continuous breed improvement programme by using of selected sires, variation in climatic conditions and availability of forage as well as inclusion or exclusion of clusters over the years. Similar findings were noted by Barazandeh *et al.* (2012), Moghbeli *et al.* (2013) and Mokhtari *et al.* (2019) in Raieni Cashmere goats, Supakorn and Pralomkarn (2012) in crossbred goats, Gupta *et al.* (2016) in Mehsana goats, Bhusan *et al.* (2019) in Jakhrana goats and Vyas *et al.* (2024) in Marwari Goats. However, non-significant effect of year of birth on KRs was observed by Ved Prakash *et al.* (2012a, 2012b) in Malpura sheep.

Season of birth had highly significant effect (P≤0.01) on KR1, but showed significant (P≤0.05) effect on KR2. In both cases, kids born during summer season had higher Kleiber ratio whereas kids born during rainy season had lowest Kleiber ratio. Kids born during rainy season have more chance to be affected by many infectious diseases and face more stressed condition due to precipitation and increased population of arthropods. These factors might affect their feed conversion efficiency which leads to lower Kleiber ratio. In the month of April and May, good availability of crop residues in the post-harvest fields facilitates ad libitum feed for dams during grazing which results into higher milk production to nourish the young ones and ultimately leads to better growth of kids. Apart from this, kids born in summer season got the opportunity to graze into two harvest season i.e. both Rabi and Kharif during 3 to 12M age. That's why the Kleiber ratio was higher for kids born in summer. Similar results were reported by Supakorn and Pralomkarn (2012) in crossbred goats whereas non-significant effect of season was found by Khadda *et al.* (2018) on KR1 in Pantja goats.

Table 1. Least square means (Mean±S.E.) of Kleiber ratios (KR) in Sirohi goat

Effect		KR1 (0-3M)	KR2 (3-12M)
Overall		16.38±0.03 (6748)	4.11±0.05 (3070)
Sire		**	**
Period of birth		**	**
	P1(2005-2009)	16.33 ± 0.04^{b} (2290)	4.05 ± 0.08^{a} (1136)
	P2(2010-2013)	16.51 ± 0.04^{c} (2018)	4.24 ± 0.08^{b} (806)
	P3(2014-2017)	16.30 ± 0.04^{a} (2440)	4.05 ± 0.08^{a} (1128)
Season of birth		**	*
	Rainy (July to Oct)	16.29 ± 0.04^{a} (2651)	4.08 ± 0.05^{a} (1037)
	Winter (Nov to Feb)	16.37 ± 0.04^{b} (3115)	4.08 ± 0.05^{ab} (1470)
	Summer (March to June)	16.48 ± 0.05^{c} (982)	4.18 ± 0.06^{b} (563)
Type of birth		**	**
	Single	16.14 ± 0.03^{a} (4423)	4.00 ± 0.05^{a} (2199)
	Multiple	16.62 ± 0.04^{b} (2325)	4.22 ± 0.05^{b} (871)
Sex		**	**
	Male	16.53 ± 0.03^{b} (3366)	4.22 ± 0.05^{b} (1002)
	Female	16.22 ± 0.03^{a} (3382)	4.00 ± 0.05^{a} (2068)
Cluster		**	**
	Vallabhnagar	16.72 ± 0.08^{c} (289)	3.89 ± 0.20^{b} (54)
	Railmagra	17.66 ± 0.05^{e} (834)	3.84 ± 0.1^{b} (328)
	Devgarh	17.41 ± 0.03^{d} (3275)	3.85 ± 0.05^{b} (1905)
	Nathdwara	17.22 ± 0.10^{d} (169)	3.33 ± 0.23^{a} (40)
	Bhadsoda	17.76 ± 0.04^{e} (1333)	4.69 ± 0.08^{d} (311)
	Karget	13.79 ± 0.08^{a} (319)	5.25 ± 0.16^{e} (169)
	Bojunda	13.99 ± 0.07^{a} (436)	3.95 ± 0.09^{c} (263)
	Salumber	16.49 ± 0.14^{b} (93)	—
Parity		**	*
	1	16.46 ± 0.04^{c} (1513)	4.17 ± 0.06^{b} (802)
	2	16.39 ± 0.04^{b} (1346)	4.12 ± 0.06^{b} (632)
	3	16.46 ± 0.04^{c} (1201)	4.13 ± 0.06^{b} (537)
	4	16.33 ± 0.05^{a} (891)	4.08 ± 0.06^{a} (403)
	5 & above	16.26 ± 0.04^{a} (1797)	4.07 ± 0.06^{a} (696)

**P ≤ 0.01, *P ≤ 0.05; Subclass means with the same superscript do not differ significantly (P ≤ 0.05)

Type of birth had highly significant (P≤0.01) effect on both KR1 and KR2. For both age durations, kids born as multiples had higher Kleiber ratio than single born kids due to compensatory growth phenomenon. Similar finding was reported by Barazandeh *et al.* (2012) in Raieni cashmere goats for KR1, Khadda *et al.* (2018) in Pantja goat only up to 6M age and Vyas *et al.* (2024) in Marwari Goats. Non-significant effect of type of birth was noted by Bhusan *et al.* (2019) in Jhakhrana goats for KR1, Mokhtari *et al.* (2019) in Raieni cashmere goats for KR1 and Dige *et al.* (2021) for KR1 in Jamunapari goats.

Highly significant effect (P≤0.01) of sex was recorded for both pre- and post-weaning Kleiber ratio and male kids showed significantly higher values than females. The results indicate better feed conversion efficiency of males than females which might be due to anabolic action of androgens. Barazandeh *et al.* (2012), Moghbeli *et al.* (2013) and Mokhtari *et al.* (2019) in Raieni cashmere goats, Supakorn and Pralomkarn (2012) in crossbred goats, Khadda *et al.* (2018) in Pantja goats and Bhusan *et al.* (2019) in Jhakhrana goats found significant effect of sex on Kleiber ratio. However, Gupta *et al.* (2016) in Mehsana goats on KR1 and Vyas *et al.* (2024) in Marwari Goats on KR2 did not report any significant effect of sex. The difference may be due to spatial or temporal variation in population under study.

Highly significant effect (P≤0.01) of cluster was observed on both traits. For KR1, Railmagra and Bhadsoda cluster showed highest values where Karget had the minimum but for the KR2, Karget had the highest value which might be due to compensatory growth phenomenon in post-weaning stage. The value of KR 2 could not be estimated for cluster Salumber due to non-availability of data of 12 months age. The performance regarding pre- and

post-weaning Kleiber ratios was comparatively higher in cluster Bhadsoda. The varaiation in estimates for different clusters are due to difference in management practices, types of vegetation consumed as well as difference in genetic properties of the population. Significant effect of cluster was also reported by Khadda *et al.* (2018) in Pantja goats and Vyas *et al.* (2024) in Marwari Goats.

Parity had also highly significant effect (P≤0.01) on KR1, but showed significant (P≤0.05) effect on KR2. Kleiber ratio was higher in kids born in up to 3rd parity. The results were in agreement with Vyas *et al.* (2024) in Marwari Goats but Khadda *et al.* (2018) in Pantja goats and Bhusan *et al.* (2019) in Jhakrana goats did not find significant effect of parity on KRs.

Heritability estimates for KR1 and KR2 were 0.65±0.07 and 0.29±0.05, respectively. The heritability estimates in our present study were very close to the heritability estimate for KR1 in Marwari goats (0.66±0.28) by Vyas *et al.* (2024). However, lower estimates were reported by Gupta *et al.* (2016) in Mehsana goats for KR1 (0.28±0.13), Khadda *et al.* (2018) in Pantja goats as 0.28±0.09, Mokhtari *et al.* (2019) in Raieni cashmere goats as 0.19±0.06, Rashidi *et al.* (2011) in Markhoz goats for KR (0-4M) as 0.27±0.05 and Supakorn and Pralomkarn (2012) in crossbred goats for KR (0-5M) as 0.35±0.04, which may be due to spatial or temporal difference in the sample. The genetic correlation between two traits was -0.66±0.10 whereas phenotypic correlation was -0.50. Thus both the correlations were negative showing that kids having higher KR in 0-3 M stage had lower KR during 3-12 M stage which might be due to compensatory growth effect. Similar findings were reported by Khadda *et al.* (2018) in Pantja goats.

CONCLUSION

The appreciable Kleiber ratio observed in Sirohi goats underscores their superior feed conversion efficiency, which is one of the most desirable economic traits for meat animals. This characteristic highlights the breed's potential for enhancing productivity in the meat industry. To maximize the profitability of goat farmers, it is essential to promote the adoption of Sirohi goats and the genetic upgrading of local herds through the use of superior Sirohi bucks, particularly within the breed's home tract. Additionally, breeding programs should be tailored to optimize the season of birth, with a focus on producing more offspring during the summer months. This timing takes advantage of favorable environmental conditions and ensures a steady supply of kids for market demand. The higher Kleiber ratio observed in multiple-born kids further suggests the potential for improving prolificacy through the use of high-quality bucks and assisted reproductive technologies (ART) at the field level. Farmers in regions with lower Kleiber ratios should also consider adopting management systems and rearing practices used by clusters with higher feed conversion efficiency. These practices could include better nutrition, disease management, and breeding strategies, all of which contribute to improving growth rates and feed efficiency. Furthermore, the medium to high heritability of the Kleiber ratio offers an excellent opportunity for individual selection. This means that through targeted breeding programs, further genetic improvement in feed efficiency can be achieved, leading to more productive and sustainable farming practices.

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