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This experiment was conducted to assess the growth performance and Kleiber ratio of weaned Boer-Central Highland goat crossbreds under different levels of concentrate supplementation in addition to grazing/browsing. A 2 x 2 x 3 factorial in randomized complete block design was used to allocate 36 crossbred goats of both sexes with the age of three months. Single and twin born kid from crossing of Boer with Central Highland goats were assigned into three feeding groups when they attained an average initial body weight of 13.6±0.81 kg. The feeding groups were: Grazing/browsing only (T_1), grazing/browsing + 1.0% of their body weight concentrate mix supplement (T_2) and grazing/browsing + 1.7% of their body weight concentrate mix supplement (T_3) on dry matter basses. Goats which received T_2 and T_3 had significantly ($p<0.05$) higher final weight than goats received T_1. The growth rate of goats which received T_2 and T_3 was 78.6% and 53.2% higher than goats which received T_1, respectively. However, the weight gain difference among goats which received T_2 and T_3 was not significant ($p>0.05$). Twin-born goats had a greater weight gain and Kleiber ratio than singletons. Sex of goats had no significant ($p>0.05$) influence on the feedlot performance. The indicative partial budget analysis also suggests that a farmer investing 1 ETB may recover the cost (1 ETB) and gain 1.73 ETB in T_2. Therefore, supplementation of weaned Boer-Central Highland crossbred goats the small amount of commercial concentrate in the proportion of in addition to grazing/browsing is recommended for improving productivity and profitability.

: Birth type, feed conversion ratio, goat sex, growth rate

In developing countries, because of the low productivity of indigenous breeds and inadequate environmental circumstances in traditional farming systems, solutions must be aimed at genetic improvement, development of new feeding strategies and improvement of farming systems (Gökdal 2000). Successful goat production requires the application of strategies that optimize the use of the environment and available nutrient sources so as to capitalize on the production potential of goat. For the effective use of native pasture, supplementation is needed in order to meet the nutritional requirements of the goats, especially for the smallholder producers (Kanani et al 2006; Silva et al 2010).

Goats reared only in pasture areas have poor performance and reach slaughter weight at an older age, when their carcass is less marketable (de Carvalho Júnior et al 2011). In an attempt to solve this problem, few producers have moved to confinement systems. However, animals in lifetime confinement tend to have greater amounts of carcass fat (de Carvalho Júnior et al 2011), which may cause their meat to be rejected by the current market. Native pasture with supplementation is an alternative system of production of goats for slaughter especially for smallholder farmers since this system combines quality with animal comfort (Carvalho et al 2011; Silva et al 2010).

Genetic improvement in most developing countries often entails crossbreeding of local breeds with breeds developed elsewhere for much higher levels of potential productivity. The Boer goat is a famous meat purpose breed for its rapid growth, excellent meat quality and high fertility (Malan 2000). This breed is originated in South Africa and was imported to Ethiopia in 2007 by the Ethiopian Sheep and Goat Improvement Program (ESGPIP). Since 2007, the Boer goat is widely used to improve growth and carcass traits of local breeds through crossbreeding. However, Boer-Central Highland goat crossbreds didn't perform well during the post-weaning period under the management of sheep and goat breeding station of Sirinka Agricultural Research Center in Amhara Regional State of Ethiopia. Besides, there is limited information on the post-weaning performance of Boer- Central Highland goat crossbreds under pasture with different levels of concentrate supplementation. Therefore, the objective of this study was to evaluate the growth performance and Kleiber ratio of weaned Boer-Central Highland goat crossbreds under different levels of concentrate supplementation in addition to grazing/browsing on native pasture.

The study was conducted in 2016 at Sirinka Agricultural Research Center which is located at 11°45’ 00" N latitude and 39°36’ 36" E longitude with the altitude of 1850 m above sea level (masl). The annual temperature ranges from 16 to 21 ºC. The rainfall pattern is bimodal: season rainfall is in February to April while season rainfall is in July to November

Thirty-six Boer-Central Highland crossbred goats at the age of three months having an average initial body weight of 13.6±0.81 kg were randomly assigned to three feeding groups (12 kids in each feeding treatment group) after 15 days of adaptation. All the kids were allowed to graze and browse on natural pasture composed of perennial browsing legume species such as pigeon pea from 8:00-11:00 hour before noon and from 13:00-16:00 hour in the afternoon. During the night, goats were kept in a semi-opened concrete barn, each goat having space area of 1 m^2. Experimental animals were monitored daily by visual appraisal to check and record the identification number of the animal, signs and time of sickness, the cause of sickness and treatment given. The visual assessment and treatment continued until the sick animal becomes healthy.

The experiment consisted a factorial combination of two sex levels, two birth types (single vs twin), and three feeding levels arranged in randomized complete block design. Goats were blocked based on initial body weight and randomly assigned to each treatment. For concentrate supplement feeding groups, concentrate feeding was practiced twice a day (half of the treatment level in the morning and the other half in the evening). There were 15 days of adaptation period before the commencement of the actual feeding. Thus, the three treatment set ups were: T_1 (control) group which was feeding only on grazing or browsing; while T_2 and T_3 groups were supplemented with concentrate mixture at the rate of 1.0% and 1.7% of their body weight on dry matter bases in addition to grazing/browsing, respectively. Mineral licks were provided in a feeding trough and clean water was provided during the daytime to all treatment groups free of choice. The amount of supplement was adjusted every week following regular weight measurement of kids throughout the experimental period. The supplemental feeds were weighed and placed in their respective treatment levels in the morning before goats go out for grazing and in the afternoon when they return from grazing/browsing. Refusal was collected and weighed daily on group bases for intake and laboratory analysis. The experiment lasted for 105 days, including 15 days of the adaptation period.

The body weight of experimental animals was taken every week after overnight fasting using scales to the nearest 200 g. Average daily weight gain in g day^{-1} (ADG) was calculated as the difference between final and initial body weights divided by the number of days of feeding experiment (90 days). Feed conversion ratio (FCR) was calculated as a proportion of daily dry matter intake to ADG. The Kleiber ratio (KR) was defined as a growth rate in g day^{-1} divided by the metabolic weight in kg.

Supplement concentrate mix feed samples were analyzed for dry matter (DM) by drying at 105 °C for 24 hours, ash by ignition in a muffle furnace at 600 °C for 6 hours, crude protein (CP) by the Kjeldahl procedure (AOAC 2006), and neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to procedures of (Decruyenaere et al 2009). The ingredients and chemical compositions of concentrate mix feed samples are presented in Table 1.

Table 1 Ingredient and chemical compositions of supplement concentrate mix feed samples

Ingredient of mix	Proportion of the mix ingredient (value in %)	Chemical Composition of mix	Value in % of DM of mix
Wheat bran	55.7	DM,% as fed	90.0
Noug seed cake	40.0	Ash,% of DM	7.8
Limestone	3.0	CP,% of DM	28.8
Salt	1.3	NDF,% of DM	20.0
		ADF,% of DM	11.1
	-	ADL,% of DM	4.4

DM = dry matter; CP =crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL= acid detergent lignin

Data were analyzed using the General Linear Model procedure of SAS (2002) to determine the effect of feed levels, sex, birth type and their interactions. Mean separation was conducted using the PDIFF option when F-test was found to be significant ($p<0.05$). The initial weight of kids was used as a covariate to minimize the error related to the initial weight difference. All two- and three-way interactions between fixed effects were found to be non-significant ($p>0.05$) and thus removed from the model. Therefore, only the values of the main effects were presented in the results part. The statistical models used were presented as follow:

$Y_{ij}= \mu + F_i + B_j + E_{ij}$…………………………………………………………………….. Model 1

Where; Y_{ij} is the response variable (feed intake and feed conversion ratio), µ is the overall mean, F_i is the effect of feeding levels and E_{ij} is the residual error.

$Y_{ijkl} = \mu + F_i + B_j + S_k + E_{ijkl}$………………………………………………………………. Model 2

Where; Y_{ijkl} is the response variable (body weight, weight gain and Kleiber ratio), µ is the overall mean, F_i is the effect of feeding levels (j = control, 1.0% and 1.7% of their body weight), B_j is the effect of birth type (j = single and twin), S_k is the effect of kid sex (k = male and female) and E_{ijkl} is the residual error.

Since the experimental kids were selected from the station, it was not possible to determine their initial and final market price. Therefore, total return (TR) was calculated as weight change * dressing percentage (46.7%) which was reported by Mekonnen et al (2014) * current meat price (140 Ethiopian birr per kg which was the average of three markets, Woldia, Mersa and Kobo). This approach of estimating total return has its own limitation since price and/or dressing percentage also varies with other variables such as animal body condition and color. But in our condition where we were not able to take out kids to market for determining their market price, estimating price by using dressing percentage is just to indicate the economic feasibility of supplemental feeding. Feed cost, labor cost and medical costs were considered as variable costs. The change in net income (ΔNI) was calculated as the difference between the change in total return (ΔTR) and the change in total variable cost (ΔTVC) as follows: ΔNI = ΔTR- ΔTVC. The marginal rate of return (MRR) measures the increase in net income (ΔNI) associated with each additional unit of expenditure (ΔTVC) and was calculated as MRR = (ΔNI/ Δ TVC) * 100.

The intake of the supplement feed and nutrients increased with the increasing level of the supplement (Table 2). Dietary protein supplementation is known to improve intake by increasing the supply of nitrogen to the rumen microbes, which increases the microbial population and efficiency. Thus, enabling an increased rate of breakdown of the digesta, which in turn increases feed intake. A better supply of escape protein in feed could also have contributed to the higher feed intake since supply of escape protein was suggested to improve feed intake (McDonald et al 1995).

In animal husbandry, feed conversion ratio (FCR) is a measure of an animal’s efficiency in converting feed mass into increases of the desired output. Numerous studies had shown that the feed conversion ratio is highly negatively correlated with average daily gain. This implies that the selection for a lower feed conversion ratio would result in a higher growth rate, or vice versa (Arthur et al 2001; Sheridan et al 2003). However, there was no significant difference ($p>0.05$) between supplemented groups in this study.

Table 2. Concentrate intake and feed conversion ratio of crossbred kids

Parameters	T_1	T_2	T_3	SEM	P-value
DM (g day^{-1})	-	164.7[b]	238.7[a]	22.4	<0.0001
% BW	-	0.91[b]	1.37[a]	0.17	<0.0001
% $BW^{0.75}$	-	1.88[b]	2.80[a]	0.26	<0.0001
CP (g day^{-1})	-	47.4[b]	68.7[a]	3.80	<0.0001

NDF (g day^{-1})	-	32.9[b]	47.7[a]	0.94	<0.0001
ADF (g day^{-1})	-	18.2[b]	26.5[a]	5.52	<0.0001
FCR (DMI g $gain^{-1}$ g)	-	6.56	7.81	2.21	0.5731

DMI = dry matter intake, BW = body weight, CP = crud protein, NDF = neutral digestible fiber, ADF = acid detergent fiber, FCR = feed conversion ratio, T_1= grazing/browsing only, T_2 = grazing/browsing + supplement 1% of their body weight, T_3 = grazing/browsing + supplement 1.7% of their body weight

The growth performance and related parameters of crossbred kids are presented in Table 3. The ADG of goats which received T_2 and T_3 was significantly ($p<0.05$) higher by 78.6% and 53.2%, respectively, over that of T_1. Feeding of high-fiber diets, as in T_1, often results in slower growth rates as compared to the feeding of high concentrate diets (Haddad 2005). Nutritional limitations reduce cell proliferation and differentiation in tissues in response to the reduced local production of insulin-like growth factor-1 (IGF-1), as signaled by the state of the relative resistance of growth

Single	14.9±0.74	16.4±0.33	30.4±3.69	3.75±0.40
Twin	12.4±0.47	17.4±0.33	42.1±3.71	4.94±0.41

[a b] Means with the same letter are not statistically different at 5% probability, T_1= grazing/browsing only, T_2 = grazing/browsing + supplement 1% of their body weight, T_3 = grazing/browsing + supplement 1.7% of their body weight

The final weight of supplemented groups in the present study is relatively higher than 13.54±0.20 kg which was reported by Deribe et al (2015) for the same crossbred goat supplemented with 200 g day^{-1} commercial concentrate in addition to grazing/browsing. Similarly, the final weight of supplemented groups in this study are also higher than the results reported by Salama et al. (2015) for Boer-Baladi goat crossbreds (13.55 kg), Baladi goat (11.41 kg) and for pure Boer goat (16.43 kg) which were supplemented a concentrate mixture at the rate of 4% of their body weight. This difference could be explained by the genetic potential of breeds, age of goats and nutrient composition of feed.

The trend for the body weight of crossbred goats is presented in Figure 1. The growth trend of crossbreds in T_2 was superior to that in T_1 and T_3. However, the trend for T_2 and T_3 seems comparable.

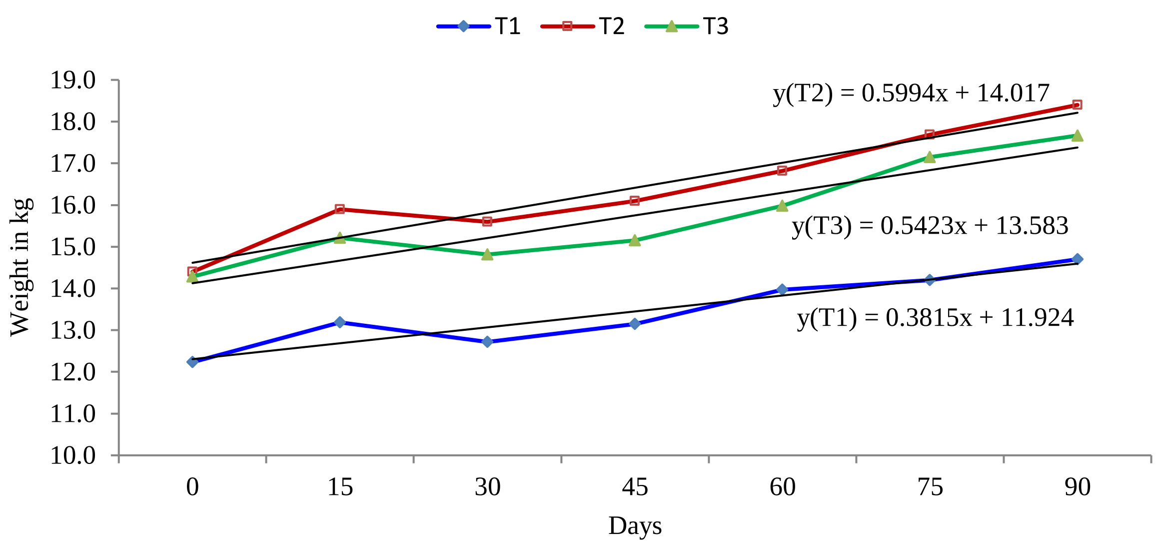

Figure 1. Body weight trends of Boer-Central Highland goat crossbreds under different feeding treatments

Kleiber ratio does not require individual intake to be measured and allows us to identify animals with a high efficiency of growth relative to body size. Thus, Kleiber ratio is the useful indicator of the efficiency of feed conversion independent of body size and an important selection criterion for efficiency of growth for goats managed semi-intensively (Kleiber 1961; Köster et al 1994). In this study, crossbreds in T_2 had higher Kleiber ratio than those in T_1 and T_3, implying that T_2 highly improved feed conversion efficiency as compared to that in T_1 and T_3.

In this study, the sex of kids had no significant ($p>0.05$) influence on all tested traits. However, twin-born kids had higher weight gain and Kleiber ratio than single born kids. The superiority of twin-born kids might be due to the compensatory growth of twins as their milk intake was lower than single-born kids in the pre-weaning stage. This suggests that twin born kids are better for fattening than singletons.

Partial budget analysis results are presented in Table 4. The results indicate that a farmer investing 1 ETB may recover the cost (1 ETB) and gain 1.73 ETB in T_2, but T_3 is dominated since investing in T_3 increases more cost than the gain as compared to T_2. This indicates that supplementing kids the small amount of commercial concentrate in the proportion of in addition to grazing/browsing is economically profitable. This result agrees with the report of Endashaw et al (2013) who noted little concentrate mix supplementation for goat under semi-intensive feeding system where better grazing pasture is available can bring more profit for goat producers. Legesse et al (2012) also reported that combining grazing with concentrate supplementation for goat provides more profit than either grazing without concentrate supplementation or pen-feeding with no grazing.

Table 4. Cost and economic returns for Boer-Central highland crossbred goat

Items	T_1	T_2	T_3	SEM
Average purchase price/head (ETB)	799.8	941.5	933.8	21.3
Average selling price/head (ETB)	1030	1165	1123	27.5
Total cost (feed+ labor + medical) /head (ETB)	95	144.4	166.6	15.1
Gross return/head (ETB)	138.4	273	231.7	27.5
Net profit/head (ETB)	43.4	129	65.1	27.5
MRR%	-	173	Dominated	-

ETB = Ethiopian birr, SEM = standard error of mean, T_1= grazing/browsing only, T_2 = grazing/browsing + supplement 1% of their body weight, T_3 = grazing/browsing + supplement 1.7% of their body weight

The findings of this study showed that concentrate mix feeding supplementary to browsing/grazing significantly increased live weight and weight gain of Boer-Central Highland goat crossbreds as compared to those feeding only on browsing/grazing. Twin-born kids had a greater weight gain and Kleiber ratio than singletons. However, the feedlot performance was not influenced by the sex of kids. From this experiment, we can understand that integrating the crossbreeding program with improved feeding management could enhance goat productivity. The indicative partial budget analysis also suggests that a farmer investing 1 ETB may recover the cost (1 ETB) and gain 1.73 ETB in supplementing kids the small amount of commercial concentrate in the proportion of in addition to grazing/browsing.

Therefore, supplementation of weaned Boer-Central Highland crossbred goats the small amount of commercial concentrate in the proportion of in addition to grazing/browsing is recommended for improving productivity and profitability.

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