Tropical Animal Health and Production (2020) 52:1239–1248
https://doi.org/10.1007/s11250-019-02123-6

REGULAR ARTICLES

Performance of kids produced by three breeds of goat fed diets supplemented with graded levels of turmeric powder

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Received: 30 January 2019 / Accepted: 21 October 2019 / Published online: 19 November 2019
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Abstract

Inclusion of some plants especially spices in the diets of farm animals have been researched upon extensively for parameters like growth, blood chemistry, and feed utilization among others. In contrary, the use of turmeric as feed additive for ruminant production is so low, while its effects on reproduction (especially during pregnancy) in ruminants are not available due to little/no information on its properties, processing, and inclusion rate. Thus, a study was conducted to evaluate pre- and post-weaning performances of kids produced by three breeds of goat fed diets supplemented with graded levels of turmeric powder intensively in southwestern Nigeria. Kids produced by Kalahari Red (KR), West African Dwarf (WAD), and KalaWAD Does fed diets containing turmeric powder (TP) at different levels were monitored for pre-weaning that lasted for 12 weeks, while selected kids were observed for 4 weeks post-weaning. Each Doe breed was fed diet at 5% bodyweight during pregnancy and pre-weaning, including some selected kids during post-weaning. Dietary treatments included concentrate diet (CD) as TP-0, CD + 2 g/kg TP as TP-2g, and CD + 5 g/kg TP as TP-5 g. *Brachiaria ruziziensis* was used as basal diet. Data obtained were arranged in a 3 × 3 factorial layout in a completely randomized design, while analysis of variance was done using SAS 9.1. Significance level was taken at 5% probability, while means were separated using Duncan's multiple range test of the same statistical package. Results of the study for breed effect revealed that KR kids had the best ($p < 0.05$) pre-weaning performance from birth (3.2 kg) till weaning (14.5 kg) and for weight gains (11.2 kg and 134.0 g/day). No mortality was recorded for WAD kids. For TP effects, the kids fed TP-2g had the highest ($p < 0.05$) weight gains (1.6 kg and 58.6 g/day) and reduced value for feed conversion ratio (FCR) of 6.2 for post-weaning performance. Kids fed TP-5g had the highest ($p < 0.05$) value for protein efficiency ratio (PER) of 1.4 at the end of post-weaning. For interaction effects of breeds and TP, KR kids fed TP-5g performed best ($p < 0.05$) at the pre-weaning period in terms of weights from birth (3.6 kg) till weaning (15.7 kg), while KR kids fed TP-2g had highest ($p < 0.05$) pre-weaning weight gains (12.5 kg and 148.9 g/day). KR kids fed TP-5g performed best ($p < 0.05$) at the post-weaning period in terms of weight gains (1.8 kg and 64.4 g/day). KR kids fed TP-2g and KalaWAD kids fed TP-5g had the lowest FCR (5.2) and the highest PER (1.6) respectively at the post-weaning period. It can be concluded that breeds of kid, TP inclusion, and their interaction influenced pre- and post-weaning performances of the kids.

Keywords Kalahari Red goat · KalaWAD goat · West African Dwarf goat · Kids' survivability · Pre-weaning · Post-weaning

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Introduction

Livestock production nowadays is faced with many factors that hinder the growth, reproduction, and yields in terms of meat, milk, and skin among others. Some of these factors include imbalanced diet in terms of quantity and quality arising from feed (forage) scarcity and seasonality; mortality- especially that of kids at early stage of life (Oderinwale et al. 2017); poor management systems and practices; and unfavorable weather conditions due to cumulative effects of climate change as it is being experienced in this century.

Concentrate supplementation to goats at various stages of growth had been reported (Mushi et al. 2009; Kawas et al. 2010) to enhance their performance. As pregnancy advances, nutrient requirements of foetus are still low, but placenta growth is essential. If growth of placental tissue is restricted by low plane of nutrition, it will be unable to adequately nourish the foetus in the final stage of pregnancy and consequently birth weight will be compromised (Acero-Camelo et al. 2008). Undernourished goats will give birth to kids of reduced birth weight, heightened mortality rates, and poor performance. Supplemental feeding during pregnancy has been shown to improve the performance and reduce mortality of kids by improving their birth weights and enhancing the immune system (Oderinwale et al. 2017).

The use of feed additives like antibiotics is of increasing concern (Gunun et al. 2016) and even banned in many countries due to the risk of appearance of antibiotic residues in meat and milk (Russell and Houlihan 2003). Due to this fact, researchers and livestock rearers have sought for alternatives to synthetic growth promoters and antibiotics in livestock production for improving growth and reproductive performances of ruminant animals. There are several benefits of turmeric if supplemented to farm animals, especially pregnant does and their offspring since no information is available for these categories of ruminant animals on turmeric supplementation.

Feeding of diets containing ethno-veterinary plants like ginger, garlic onion, coriander, etc. to livestock has been in practice for a long period of time. But there is very little or no information on the application, inclusion rate, and effects of turmeric powder supplementation on ruminant production especially goat. These plants play vital role in improving the health, feed efficiency, and overall animal performance.

Turmeric (*Curcuma longa*) is a spice that originates from Southwest India, which contains an active compound known as curcumin. This compound is believed to have a wide range of biological effects such as anti-inflammatory, antioxidant, antitumor, antibacterial, and antiviral activities among others (Prasad et al. 2011). Research (Biedrzycka 2003) showed that certain spices contain properties, which make the digestive process of ruminant animals more efficient, thereby producing less waste and thus improved performance in terms of growth. The study was therefore conducted to evaluate the pre- and post-weaning performances of kids produced by Kalahari Red, KalaWAD, and West African Dwarf goats fed diets supplemented with graded levels of turmeric powder intensively in southwestern Nigeria.

Materials and methods

Experimental site

The experiment was conducted at the Kalahari Red Goats Unit of Livestock Production and Research Programme Farm under Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. The region is 76 m above the sea level and falls within latitude 7° 13′ 47.41″ N and longitude 3° 23′ 43.48″ E. The climate is humid and located in the forest zone of southwestern Nigeria.

Source of experimental animals

The Kalahari Red, KalaWAD, and West African Dwarf goats used for the study were sourced from IFSERAR, Federal University of Agriculture Abeokuta, Nigeria.

Brief information on selected breeds of goat used for the study

Kalahari Red goats

The Kalahari Red is regarded as an indigenous goat breed that originates from South Africa. Records indicated that the goats have been selected from lop-eared animals that migrated with various tribes of people to the southern part of Africa more than 2000 years ago (Epstein 1971). This breed of goat is an important meat-producing animal in South Africa with characteristics such as adaptation to arid and semi-arid savannah, good foraging, and excellent mothering abilities. It is regarded as a "minimum care/maximum profit" breed (Ramsay et al. 2001).

WAD goat

This breed is confined to the tropical forest belt of Southern Nigeria and other West African countries such as the Cameroon. The West African Dwarf (WAD) goats appear to be the only breed that is able to survive and successfully reproduced in tsetse fly infested humid forest areas of west and central Africa, i.e., it is a trypano-tolerant goat breed (Odubote et al. 1992). The goats are small in size, short-legged, and are higher than 50 cm in height at withers. The average live weight is 20 kg for the goats (Steele 1996). This breed has a variety of coat color, but black and brown

colors predominate. Mature females have tassels. It is common for both mature males and females to have beard. The breed is highly prolific with a high percentage of twining and triplets, thereby satisfying a part of the meat requirement in Nigeria where it is found.

KalaWAD goat

KalaWAD is a product resulting from the crossing of pure Kalahari Red bucks and WAD does. The crosses were bred under Livestock Production and Research Programme of Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture Abeokuta, Ogun State, Nigeria, in the year 2013. The crosses are better in terms of weight gain and growth rate than WAD goats. The skin coat colors can be pure brown, brown with black patches, black with brown patches, and mixture of more than two colors just like WAD goats. KalaWAD goats adapt well to the environment and they are also trypano-tolerant. Multiple birth type like twinning is also common in them just as it is in WAD goats.

Preparation of turmeric powder

Fresh turmeric rhizomes were sourced from a reputable market in Ibadan, Oyo State, Nigeria. The rhizomes after purchase were sorted to remove unwanted materials and dirt. Washing with cool ordinary water was done after sorting to further cleanse the rhizomes; this was followed by draining and spreading in a cool dry place on clean trays to allow air-drying for about 24 h. Slicing was done thereafter with the use of sharp knives into smaller pieces and oven dried at 60°C to a constant weight. The dried rhizomes were then milled into fine powder using an electric blender before its inclusion in the experimental diets and for necessary analyses. The flowchart for the preparation is presented in Fig. 1.

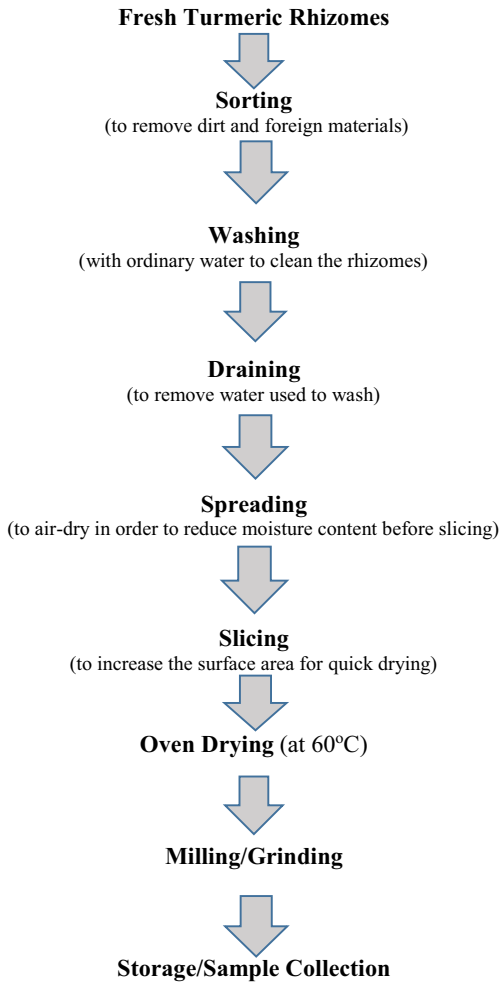

Fig. 1 Flowchart showing preparation of turmeric powder

Atmospheric data collection

The ambient temperature taken in the morning (8:00 am) and afternoon (1:00 pm) on daily basis using atmospheric thermometer during the course of the study is presented in Table 1. The mean annual precipitation of the experimental site was 1,330 mm with an average relative humidity of 80% throughout the year.

Management procedure for Does

Forty-five matured, dry, and non-lactating Does of 2 to 2.5 years were used. These included 15 Kalahari Red (KR), 15 KalaWAD, and 15 WAD does. The Does were balanced for weight, tagged, and randomly allotted to 3 treatment groups comprising of 5 Does as replicates per treatment. Each Doe was housed in an individual cubicle measuring 1.2 × 1.4 m^2. Flock treatment was done prior to mating using antibiotic,

Table 1 Monthly ambient temperature (°C) in the morning (8:00 am) and afternoon (1:00 pm) at the experimental site

Months	Temperature (°C) at 8:00 am			Temperature (°C) at 1:00 pm		
	Mean	Min	Max	Mean	Min	Max
January	24.8	21.0	28.0	33.2	30.5	35.5
February	25.4	17.5	30.0	34.4	31.5	37.0
March	26.6	24.0	29.0	35.1	29.5	37.5
April	26.0	24.0	29.0	34.2	31.0	37.0
May	25.0	24.0	26.0	32.6	29.5	35.5
June	24.2	22.0	26.0	31.2	27.0	35.5
July	23.8	22.0	25.0	29.1	27.0	30.5
August	24.4	24.0	25.0	29.1	27.0	31.0
September	24.8	24.0	26.0	30.2	27.5	34.0
October	24.8	23.0	29.5	31.8	29.0	34.0
November	26.8	26.0	27.0	33.7	33.0	34.0
December	25.8	21.0	27.0	33.5	32.0	35.0

vitamin supplement and anti-stress, and anthelminthic to control gastrointestinal worms, fly larvae, lice, ticks, and mites. The experimental diets were used for flushing of the Does for 2 weeks before the commencement of the study and throughout the experimental period.

The Does were synchronized during flushing period with first intramuscular injection of Lutalyse® which contains 5 mg/ml dinoprost triomethamine injection. Second injection was given to the Does 10 days after first injection at same dosage according to the procedure of Heise (2012). Thereafter, mating of the synchronized Does was done by introducing 6 proven KR bucks (i.e., 2 bucks per breed of goat) into the pens where the Does were housed for 6 h/day (between 4:00 pm to 7:00 pm and 7:00 am to 10:00 am) for 1 week. Proper observation was done to ensure successful mating of each Doe by the selected KR bucks in terms of intromission and ejaculation before data collection commenced. The does were scanned after 30 days of successful mating by ultrasonography method using 3.5-MHz linear array probe (Kaikin, China) and ultrasound scanning machine (Draminski Animal Profi Ultrasound Scanner NimH 12 V; 3.8 Ah; 45 °C). All the Does that did not conceive after the scanning went through the synchronization and mating cycle again.

The live weight of each kid kidded per Doe in each treatment was taken within 24 h of birth using a 20-kg platform scale after the body was dried using a clean dry towel. All the kids produced by the Does were used for pre-weaning performance and survivability that lasted for 12 weeks after kidding, while post-weaning performance and survivability lasted for 4 weeks for selected kids (Table 2).

Table 2 Gross compositions (%) of basal experimental concentrate diet

Ingredients	% Inclusion
Maize	15.0
Wheat offal	42.0
Palm kernel cake	30.0
Soybean meal	4.0
Groundnut cake	3.0
Bone meal	3.0
Limestone	1.5
Common salt	1.0
Premix*	0.5
Total (kg)	100

*Contains vitamin A (IU) 10,000.000; vitamin D_2 (IU) 2,000,000; vitamin E (IU) 20,000; vitamin K (mg) 2250; riboflavin (mg) 5000; pyridoxine (mg) 275; biotin (mg) 50; pantothenic acid (mg) 7500; vitamin B_1 (mg) 175; vitamin B_{12} (mg) 15.0; niacin (mg) 27,500; folic acid (mg) 7500; choline chloride (mg) 400; antioxidant (mg) 125; Fe (g) 20.0; Zn (g) 50.0; Mn (g) 80.0; Cu (g) 5.0g; I (g) 12.0; Co (mg) 200; Se (mg) 200

Experimental diets

1. TP-0: Basal concentrate diet (control)
2. TP-2g: Basal concentrate diet + 2 g/kg turmeric powder
3. TP-5g: Basal concentrate diet + 5 g/kg turmeric powder

Feeding procedure for Does before birth and during pre-weaning

The pregnant Does were fed for 24 weeks (162 days) until they all kidded. Experimental diets were fed to the Does throughout the feeding trial (during pregnancy and pre-weaning period) at 5% body weight twice in a day with concentrate diet in the morning by 08:00, while stall-feeding was done using Congo grass (*Brachiaria ruziziensis*) in the evening by 04:00. Concentrate and grass refused each day were recorded before fresh ones were offered on the following day. Cool and clean drinkable water was available to the Does *ad libitum*. All the kids produced were used for the pre-weaning performance. The kids after birth were housed with their respective dams in individual cubicles. Birth weights of individual kid was taken, thereafter, the weight was taken fortnightly to monitor their growth. Any case of kid mortality was reported to the veterinarians on the farm to ascertain the cause.

Feeding procedure for selected kids during post-weaning

A total of 54 kids were selected from Does fed the experimental concentrate diets after weaning. The selected kids were allotted to three treatment groups comprising of 6 kids as replicates per treatment. Each kid was housed in an individual cubicle. The kids were balanced for sex and weight. Live weight of each kid was taken at the start of post-weaning as initial weight. Thereafter, individual weight of the kids was taken weekly before feeding throughout the post-weaning period that lasted for 4 weeks. Experimental diets were fed to the kids at 5% of their body weight twice in a day with concentrate diet in the morning by 08:00, while stall-feeding was done using Congo grass (*Brachiaria ruziziensis*) in the evening by 04:00. Concentrate and grass refused each day were recorded before fresh ones were offered on the following day. Cool and clean drinkable water was available to the kids *ad libitum*.

Kid survivability

Survivability of kids kidded by the experimental Does under each treatment group was monitored from kidding till 16th week after birth (i.e., 4 months). Any case of kid mortality within the period was recorded. The cause(s) of mortality that

occurred during the period was ascertained as much as possible with the assistance of veterinarians on the farm.

Proximate and fiber analysis of concentrate, turmeric powder, and grass fed

Samples were taken from dietary concentrates, turmeric powder, and *Brachiaria ruziziensis*. The samples were milled and kept until when needed for proximate composition and fiber analyses according to the procedure of AOAC (2005).

Statistical analysis

Data obtained were arranged in a 3 × 3 factorial layout in a completely randomized design, while analysis of variance was done using the procedures of Statistical Analysis System (SAS) (2004). Significant level was taken at 5% probability, while means were separated using Duncan's multiple range test of the same statistical package.

Experimental factors included:

Factor A: Goat breeds (Kalahari Red, KalaWAD, and West African Dwarf goats)

Factor B: Experimental concentrate diets (TP-0, TP-2g, and TP-5g)

Statistical model

$$Y_{ijkl} = \mu + T_i + R_j + (\mathrm{TR})_{ij} + \mathcal{E}_{ijkl}$$

where

Y_{ijkl}	Observed performance indices
μ	Goats' population mean
T_i	Effects of goat breeds
R_j	Effects of experimental concentrate diets
$(\mathrm{TR})_{ij}$	Interactive effects of breeds and diets
$\mathcal{E}_{ijkl}$	Residual effect/error term

Experimental formulae

$$\text{Organic Matter}(\%) = 100 - \text{Ash}$$

$$\text{Hemicellulose}(\%) = \text{Neutral Detergent Fibre} - \text{Acid Detergent Fibre}$$

$$\text{Cellulose}(\%) = \text{Acid Detergent Fibre} - \text{Acid Detergent Lignin}$$

$$\text{Weight Gain}(\text{kg}) = \text{Final weight}(\text{kg}) - \text{Initial weight}(\text{kg})$$

$$\frac{\text{Weight Gain}(\text{g/day}) = \text{Weight gained}(\text{g})}{\text{Gestation Length}(\text{days})}$$

$$\frac{\text{Feed Conversion Ratio} = \text{Total Feed Consumed}(\text{g})}{\text{Weight gained}(\text{g})}$$

$$\text{ProteinEfficiencyRatio} = \frac{\text{Weightgained}(\text{g})}{\text{Totalcrudeproteinintake}(\text{g})}$$

$$\text{ME}(\text{MJ/kgDM}) = 12.86 + 0.0265\text{EE} + 0.0056\text{ADF} + 0.0153\text{ASH} - 0.0253\text{ADL}$$

where

ME	metabolizable energy
DM	dry matter
EE	ether extract
ADF	acid detergent fiber
ADL	acid detergent lignin

Results and discussion

The proximate and fibre fraction compositions of experimental diets are presented in Table 3. Dry matter (DM) contents of the diets were 88.2% for TP-0, 86.6% for TP-2g, and 86.5% for TP-5g. The crude protein (CP) ranged between 12.7 and 18.5%. This shows that the diets supplied sufficient CP to meet the amount required by the pregnant goats. This is in line with the report of NRC (2007) that recommended CP of 9–10% and 13–14% for early and late gestations, respectively, for goats. TP-2g had the highest CP content, followed by TP-0 (16.5%) while TP-5g had the least value (12.7%). Nutrient binding was observed for turmeric powder inclusion (TPI)

Table 3 Proximate and fibre fraction compositions of experimental diets

Parameters (%)	TP-0	TP-2g	TP-5g
Dry matter	88.2	86.6	86.5
Crude protein	16.5	18.5	12.7
Ether extract	2.5	2.5	1.8
Crude fibre	27.5	25.2	24.6
Ash	11.0	9.3	6.5
Nitrogen free extract	41.7	40.5	47.4
Organic matter	89.0	90.6	93.5
Neutral detergent fibre	62.7	66.0	62.4
Acid detergent fibre	38.0	40.9	44.3
Acid detergent lignin	10.7	11.3	16.4
Hemicellulose	24.7	25.3	18.1
Cellulose	27.3	29.3	27.9
ME* (MJ/kg DM)	12.3	12.3	12.1

ME metabolizable energy

*Calculated using De Boever et al. (1997) equation

especially at 5 g/kg for CP, ether extract (EE), crude fiber (CF), and ash after proximate analyses were conducted for three times at two different laboratories. Other parameters for proximate and fibre fraction analyses did not follow a uniform pattern. For instance, basal concentrate diet (BCD) with 16.5% CP was reduced to 12.7% with 5 g/kg TPI compared to other diet fed. The reason for the binding could not be ascertained, but likely to be as a result of curcumin found in turmeric which binds some nutrients as its inclusion increases. Values obtained for other proximate parameters such as EE, CF, ash, nitrogen free extract (NFE), and organic matter (OM) ranged between 1.8–2.5%, 24.6–27.5%, 6.5–11.0%, 40.5–47.4%, and 89.0–93.5%, respectively, for the diets. Dietary fibre fractions such as neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), hemicellulose, and cellulose ranged between 62.4–66.0%, 38.0–44.3%, 10.7–16.4%, 18.1–25.1%, and 27.3–29.3%, respectively. The metabolizable energy obtained for the diets ranged between 12.1 and 12.3 MJ/kg DM, the value which was in line with 11.0 MJ/kg DM recommended for goats.

Table 4 shows proximate composition, fibre fractions, and some vitamin assay of *Brachiaria ruziziensis* and turmeric powder. The results obtained for proximate composition of turmeric powder revealed that the DM was 86.4%. The value was close to that of Feedipedia (2018) which reported DM content of turmeric to be 89.5%. The values reported by other researchers were higher than that obtained for the study. Youssef et al. (2014) reported DM content of 93.4%, while 91.0% was reported by Ahamefula et al. (2014). CP of 13.3% was obtained for turmeric, whereas lower CP content ranging from 4.6 to 9.4% was reported in other studies (Ahamefula et al. 2014; Youssef et al. 2014; Feedipedia 2018). Variations in the values for CP might be due to processing methods, soil nutrient composition, and effect of location. CF content obtained for turmeric in the study was 24.2% which was close to 38.4% reported by Feedipedia (2018), whereas lower values of 4.0% and 4.6% were reported by Youssef et al. (2014) and Ahamefula et al. (2014), respectively. Values obtained for ash content, EE, and NFE of turmeric were similar to what was reported by Feedipedia (2018). Energy content of 12.4 MJ/kg DM was obtained, the value which was lower than 18.0 MJ/kg DM reported by Feedipedia (2018) for turmeric. The variation might be due to procedures employed in estimating the energy content. Values obtained for other proximate parameters such as EE, CF, ash, NFE, and OM of turmeric were 2.7%, 24.2%, 5.1%, 46.1%, and 94.9%, respectively. Fibre fractions such as NDF, ADF, ADL, hemicellulose, and cellulose were 66.7%, 38.7%, 8.0%, 28.0%, and 30.7%, respectively, for turmeric. Values of some vitamins assayed using turmeric were 19.0 mg/kg, 1.4 mg/kg, and 5.6 mg/kg for vitamins A, C, and E, respectively.

Table 4 Proximate composition, fibre fractions, and some vitamin assay of *Brachiaria ruziziensis* and turmeric powder

Parameters (%)	*Brachiaria ruziziensis*	Turmeric powder
Dry matter	89.1	86.4
Crude protein	8.0	13.3
Ether extract	2.4	2.7
Crude fibre	24.5	24.2
Ash	7.8	5.1
Nitrogen free extract	54.2	46.1
Organic matter	92.2	94.9
Neutral detergent fibre	65.3	66.7
Acid detergent fibre	45.3	38.7
Acid detergent lignin	13.3	8.0
Hemicellulose	20.0	28.0
Cellulose	32.0	30.7
ME* (MJ/kg DM)	12.2	12.4
Vitamin assay (mg/kg)		
A	NA	19.0
C	NA	1.4
E	NA	5.6

ME metabolizable energy, *NA* not analyzed

*Calculated using De Boever et al. (1997) equation

DM (89.12%) for *Brachiaria* used for the study was similar to that reported by Feedipedia (2018). The CP obtained was 8.0% which was higher than 4.6% that was reported by Feedipedia (2018). The variation in the CP content might be due to various factors ranging from soil nutrients, part(s) of the plant used for analysis, season of harvest, and geographical location. The values of EE, CF, ash, NFE, and OM were 2.4, 24.5, 7.8, 54.1, and 92.2%, respectively. These values for *Brachiaria* were inconsistent with the results obtained by other authors (Maia et al. 2014; Feedipedia 2018). These variations might be due to part(s) of the plant used for analysis, season of harvest and geographical location. Values obtained for other proximate parameters such as EE, CF, ash, NFE, and OM were 2.4%, 24.5%, 7.8%, 54.2%, and 92.2%, respectively for *Brachiaria*. Fibre fractions such as NDF, ADF, ADL, hemicellulose, and cellulose had 65.3%, 45.3%, 13.3%, 20.0%, and 32.0%, respectively, for *Brachiaria*.

Body weights and growth rates in pre-weaning are often considered as an early indicator of the late growth and economic benefit, and can affect body weight at puberty and at first kidding (Portolano et al. 2002; Hanford et al. 2006). Table 5 shows effects of breeds of goat kids on performance and mortality from birth to 4 weeks post-weaning. Kids produced by KR Does had the overall best growth performance at pre- and post-weaning periods, followed by kids from KalaWAD and lastly by WAD kids. KR kids had the highest weight at birth (3.2 kg), followed by KalaWAD (2.4 kg), while WAD kids had the least value of 1.9 kg. Weaning weight of 14.5 kg was obtained for KR kids which was the highest, followed by KalaWAD kids with 11.2 kg. WAD kids had the least weight of 7.8 kg at week 12 when weaning was done.

Table 5 Effects of breeds of goat kids on performance and mortality from birth to 4 weeks post-weaning

Parameters	KR kids	KalaWAD kids	WAD kids	SEM
Pre-weaning performance				
Weight at birth (kg)	3.2[a]	2.4[b]	1.9[c]	0.9
Weight at week 2 (kg)	5.2[a]	4.2[b]	3.1[c]	0.2
Weight at week 4 (kg)	7.1[a]	5.4[b]	4.2[c]	0.3
Weight at week 6 (kg)	8.7[a]	7.1[b]	5.3[c]	0.3
Weight at week 8 (kg)	10.5[a]	8.5[b]	6.1[c]	0.4
Weight at week 10 (kg)	12.2[a]	9.8[b]	6.9[c]	0.5
Weight at week 12 (kg)	14.5[a]	11.2[b]	7.8[c]	0.6
Weight gain (kg)	11.2[a]	8.7[b]	5.8[c]	0.5
Daily weight gain (g/day)	134.0[a]	103.3[b]	69.4[c]	6.0
Mortality (%)	5.0[b]	20.0[a]	0.0[c]	0.3
Post-weaning performance				
Grass intake (gDM/day)	61.8	55.5	68.0	6.5
Conc. intake (gDM/day)	299.9[a]	257.8[b]	292.2[a]	11.4
Total FI (gDM/day)	361.8[a]	313.3[b]	360.3[a]	14.3
Final weight (kg)	12.1[a]	11.9[b]	11.8[c]	0.2
Weight gain (kg)	1.5	1.3	1.3	0.0
Daily weight gain (g/day)	54.1	47.3	45.1	0.6
Feed conversion ratio	7.4	7.7	10.4	1.5
Protein efficiency ratio	1.1	1.1	0.9	0.1
Mortality (%)	10.0[a]	0.0[b]	0.0[b]	0.0

Means on the same row having different letters are significantly different ($p < 0.05$)

KR Kalahari Red, *WAD* West African Dwarf, *DM* dry matter, *FI* feed intake

Weight gains obtained for the pre-weaning period were 11.2 kg and 134.0 g/day for KR kids. WAD kids had the least weight gains of 5.8 kg and 69.4 g/day. KR kids were heaviest and performed better than kids of other breeds; this may be due to big size of KR compared to other breeds used. There is a direct and linear relationship between dams' weight and kids produced. This is corroborated by Mandal et al. (2006) who reported that reproductive process, birth weight, and early growth rate of animals are determined not only by genetic potential but also by maternal and environmental factors. KR kids had the highest mortality (20%), followed by KalaWAD kids with 5%. None of the WAD kids died during the study at the pre-weaning stage. This suggests hardiness of WAD which is being transferred to their offsprings since mortality is always very high at early stage of life for goat kids.

KR kids had the highest concentrate and total feed intakes at the post-weaning period that lasted for 4 weeks. Total feed intakes of 361.8 and 313.3 g DM/day were obtained for kids by KR and KalaWAD, respectively. This indicated that KR kids consumed much due to their big size compared to kids of other breeds. KR kids also had the highest final weight of 12.1 kg, followed by KalaWAD kids with 11.9 kg, while WAD kids had the least value (11.8 kg) at the post-weaning phase. KR kids had marginally highest values for all other post-weaning parameters taken (except for FCR with lowest value), while WAD kids had least values for same parameters (except for FCR with highest value). No mortality was recorded for WAD and KalaWAD kids at post-weaning phase, whereas KR kids had 10% mortality. This is an indication that WAD and KalaWAD with no kid mortality were more hardy and resilient than KR kids.

Effects of levels of turmeric powder inclusion (TPI) on performance and mortality of goat kids from birth to 4 weeks post-weaning is presented in Table 6. Supplementation of turmeric powder had no significant effect on all the pre-weaning parameters taken except for mortality. Kids of Does fed diet containing turmeric powder especially at 2 g/kg had overall best pre-weaning growth performance than the control group. This corroborates the report of Sameh et al. (2018) who reported that kids of Baladi, Damascus, and Zaraibi goats supplemented with antioxidant had overall best pre-weaning performance, especially weaning weight compared to other groups without antioxidant supplementations. Kids of Does fed diet without turmeric had the highest mortality (14.3%), while kids of Does fed diet containing turmeric had the least values of 4.5% and 5.0% for TP-2g and TP-5g, respectively, at the pre-weaning stage. Post-weaning parameters such as grass intake, final weight, weight gains, FCR, PER, and mortality were influenced by TPI. Kids fed TP-0 had the highest grass intake of 73.2g/day DM, while 54.3g/day DM was obtained for kids fed TP-2g which was the least intake for grass. Kids fed TP-2g had the highest values of final weight (12.2 kg) and

Table 6 Effects of levels of turmeric powder inclusions on performance and mortality of goat kids from birth to 4 weeks post-weaning

Parameters	TP-0	TP-2g	TP-5g	SEM
Pre-weaning performance				
Weight at birth (kg)	2.4	2.4	2.6	0.9
Weight at week 2 (kg)	3.9	4.0	4.0	0.2
Weight at week 4 (kg)	5.0	5.6	5.3	0.3
Weight at week 6 (kg)	6.3	7.1	6.6	0.3
Weight at week 8 (kg)	7.4	8.3	7.9	0.4
Weight at week 10 (kg)	8.6	9.5	8.9	0.5
Weight at week 12 (kg)	9.6	11.5	9.9	0.6
Weight gain (kg)	7.2	9.1	7.4	0.5
Daily weight gain (g/day)	85.7	108.2	88.5	6.0
Mortality (%)	14.3^{a}	4.5^{b}	5.0^{b}	0.1
Post-weaning performance				
Grass intake (gDM/day)	73.2^{a}	54.3^{b}	57.9^{ab}	5.6
Conc. intake (gDM/day)	277.4	294.3	278.2	9.7
Total feed intake (gDM/day)	350.6	348.5	336.1	12.4
Final weight (kg)	11.5^{b}	12.2^{a}	12.1^{a}	0.2
Weight gain (kg)	0.9^{b}	1.6^{a}	1.5^{a}	0.0
Daily weight gain (g/day)	33.4^{b}	58.6^{a}	54.5^{a}	0.6
Feed conversion ratio	12.3^{a}	6.2^{b}	7.0^{b}	1.3
Protein efficiency ratio	0.6^{c}	1.0^{b}	1.4^{a}	0.1
Mortality (%)	4.8^{a}	4.5^{ab}	0.0^{b}	0.0

Means on the same row having different letters are significantly different ($p < 0.05$)

DM dry matter, *TP-0* without turmeric, *TP-2g* 2 g/kg turmeric powder inclusion, *TP-5g* 5 g/kg turmeric powder inclusion

weight gains (1.6 kg and 58.6 g/day). The kids also recorded lowest value of 6.2 for FCR which indicated better feed utilization. PER was highest (1.4) for kids fed TP-5g which is an indication of better protein utilization by the kids. Kids fed TP-5g had no mortality at the post-weaning phase compared to the kids fed diet without TPI with 4.8% as the highest mortality recorded for the study. Diarrhoea was the major cause of mortality recorded for kids fed diet without turmeric powder, whereas mortality recorded for kids fed diets with TPI were either as a result of snake bite, strangulation, or unknown cause. The effects of turmeric powder on mortality could be as a result of the antimicrobial, antioxidant (Prasad et al. 2011) and antidiarrhoeal properties of curcumin contained in turmeric which served as growth promoters for the kids, thus reduced mortality observed.

The effects of breeds of goat kids and levels of TPI on growth performance and mortality from birth to post-weaning are presented in Table 7. The table showed that kids fed diets with TPI had overall improved growth performance compared to kids of the control group. For pre-weaning performance, kids of KR fed TP-5g had the highest body weights from kidding till week 11. KR kids fed TP-2g had the highest body weight at 12th week when weaning was done. The KR kids fed TP-2g also had the highest values for weight gains (12.5 kg; 148.9 g/day). Highest kid mortality of 28.6% was obtained for KalaWAD.

Table 7 Effects of breeds of goat kids and levels of turmeric powder inclusions on performance and mortality from birth to post-weaning

	Kalahari Red kids			KalaWAD kids			WAD kids			
Parameters	TP-0	TP-2g	TP-5g	TP-0	TP-2g	TP-5g	TP-0	TP-2g	TP-5g	SEM
Pre-weaning performance										
Weight at birth (kg)	3.0^{bc}	3.2^{ab}	3.6^{a}	2.1^{def}	2.5^{cde}	2.6^{cd}	2.0^{ef}	1.8^{f}	$2.0e^{f}$	0.9
Weight at week 2 (kg)	4.6^{bc}	5.3^{ab}	5.9^{a}	3.9^{cde}	4.5^{bc}	4.1^{bcd}	3.5^{cde}	2.8^{e}	3.1^{ed}	0.2
Weight at week 4 (kg)	$6.0b^{cd}$	7.5^{ab}	7.7^{a}	5.1^{cde}	6.4^{abc}	4.9^{cde}	$4.3d^{e}$	3.8^{e}	4.5^{de}	0.3
Weight at week 6 (kg)	7.2^{bc}	8.9^{ab}	10.3^{a}	6.7^{c}	8.8^{ab}	5.9^{c}	5.6^{c}	5.2^{c}	5.2^{c}	0.3
Weight at week 8 (kg)	8.8^{bc}	10.7^{ab}	12.3^{a}	7.5^{cd}	10.5^{ab}	7.4^{cd}	6.3^{cd}	5.9^{d}	6.1^{cd}	0.4
Weight at week 10 (kg)	10.8^{abc}	12.3^{ab}	14.1^{a}	9.0^{bcd}	11.4^{ab}	9.2^{bcd}	7.0^{cd}	7.1^{cd}	6.5^{d}	0.5
Weight at week 12 (kg)	12.1^{ab}	15.7^{a}	15.7^{a}	10.0^{bc}	13.6^{ab}	10.0^{bc}	7.8^{c}	8.1^{c}	7.3^{c}	0.6
Weight gain (kg)	9.0^{bc}	12.5^{a}	12.1^{ab}	7.6^{cd}	10.9^{ab}	7.5^{cd}	5.8^{cd}	6.3^{cd}	5.4^{d}	0.5
Daily weight gain (g/day)	107.4^{bc}	148.9^{a}	144.5^{ab}	90.8^{cd}	129.7^{ab}	89.5^{cd}	68.7^{cd}	74.7^{cd}	64.0^{d}	0.6
Mortality (%)	14.3^{b}	0.0^{c}	0.0^{c}	28.6^{a}	14.3^{b}	16.7^{b}	0.0^{c}	0.0^{c}	0.0^{c}	0.5
Post-weaning performance										
Grass intake (gDM/day)	79.7^{ab}	43.3^{c}	62.4^{ab}	57.8^{bc}	61.7^{ab}	47.1^{c}	82.2^{a}	57.8^{bc}	64.1^{ab}	1.1
Conc. intake (gDM/day)	286.9^{ab}	307.0^{a}	306.0^{a}	257.1^{ab}	273.0^{ab}	243.3^{b}	288.3^{ab}	302.9^{a}	285.5^{ab}	15.3
Total FI (gDM/day)	366.6^{a}	350.3^{ab}	368.4^{a}	314.9^{ab}	334.6^{ab}	290.4^{b}	370.5^{a}	360.7^{a}	349.6^{ab}	21.8
Final weight (kg)	11.5^{bc}	12.3^{a}	12.3^{a}	11.3^{c}	12.3^{ab}	12.1^{abc}	11.7^{abc}	11.9^{abc}	11.8^{abc}	0.3
Weight gain (kg)	0.9^{bc}	1.8^{a}	1.8^{a}	0.7^{c}	1.7^{ab}	1.5^{abc}	1.1^{abc}	1.4^{abc}	1.3^{abc}	0.3
Daily weight gain (g/day)	33.9^{bc}	64.1^{a}	64.4^{a}	25.7^{c}	61.9^{ab}	54.4^{ab}	40.7^{abc}	49.8^{abc}	44.9^{abc}	1.1
Feed conversion ratio	11.4^{ab}	5.2^{b}	5.6^{b}	12.2^{ab}	5.4^{b}	5.4^{b}	13.2^{a}	8.0^{b}	10.1^{ab}	2.3
Protein efficiency ratio	0.6^{cd}	1.1^{bc}	1.4^{ab}	0.5^{d}	1.1^{bc}	1.6^{a}	0.7^{cd}	0.8^{cd}	1.1^{abc}	0.2
Mortality (%)	14.3^{a}	14.3^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.00

Means on the same row having different letters are significantly different ($p < 0.05$)

WAD West African Dwarf, *DM* dry matter, *FI* feed intake, *TP-0* without turmeric, *TP-2g* 2 g/kg turmeric powder inclusion, *TP-5g* 5 g/kg turmeric powder inclusion

For post-weaning performance, kids of WAD fed TP-0 had the highest value for total feed intake (370.5 g DM/day). In contrast to total feed intake, KR kids fed TP-2g had overall best performance for post-weaning in terms of final weight, weight gains, and FCR, whereas PER was highest for KalaWAD kids fed TP-5g. The results corroborated the report of Földešiová et al. (2015) for New Zealand White rabbit fed diets supplemented with turmeric powder. Rabbits fed diets with turmeric powder had improved weight gains compared with the control group, especially at 5 g/kg inclusion rate. Karami et al. (2010) also reported that goat bucks fed diets supplemented with 0.5% (w/w) of turmeric powder had highest values for weight gain and daily weight gain than other dietary treatments. Post-weaning kid mortality of 14.3% was obtained for KR fed TP-0 and TP-2g, while none was recorded for other diets.

Conclusions

It could be concluded from the results obtained for the study that breeds of kids, turmeric powder inclusion (TPI), and the interaction between breeds of kids and turmeric powder influenced pre- and post-weaning performances, and survivability of the kids. For the breed effects, Kalahari Red (KR) kids had the best pre-weaning performance from birth till weaning and weight gains, and final post-weaning weight. No pre-weaning kid mortality was recorded for West African Dwarf (WAD) kids.

For effects of TPI, kids fed diet containing turmeric powder especially at 2 g/kg had the highest final weight, weight gains, and reduced value for feed conversion ratio (FCR) for post-weaning performance. Kids fed diet with turmeric powder at 5 g/kg had the highest value for protein efficiency ratio (PER) at the end of post-weaning. The reasons for the effects of turmeric powder observed could be as a result of the anti-microbial, anti-oxidant and anti-diarrhoeal properties of curcumin found in turmeric which served as growth promoters for the kids and reduced mortality observed.

Interaction effects had KR kids fed diet with turmeric powder at 5 g/kg performed best at the pre-weaning period in terms of weights from birth till weaning, and also had the highest pre-weaning weight gains. KR kids fed diet with turmeric powder at 5 g/kg performed best at the post-weaning period in terms of final weight and weight gains. KR kids fed diet with turmeric powder at 2 g/kg and KalaWAD kids fed diet with turmeric powder at 5 g/kg had the lowest and highest values for FCR and PER, respectively, at the post-weaning period.

Funding information This research is supported by the World Bank through Africa Centre of Excellence in Agricultural Development and Sustainable Environment (CEADESE) with Grant No. ACE 023. The research was partly funded by Tertiary Education Trust Fund (TETFund), which was facilitated by Directorate of Grants Management and Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture Abeokuta, Nigeria.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of animal rights All applicable international, national, and institutional guidelines for the care and use of animals were followed in the conduct of this research.

Informed consent Informed consent was obtained from all individual participants included in this study.

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