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Improvement of growth performance and meat sensory attributes through use of dried goat rumen contents in broiler diets

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The study investigated the use of dried goat rumen contents (DGRC) on growth performance of broiler chickens. Rumen contents were obtained from goats immediately after slaughter during the wet season, sundried, milled and incorporated in experimental diets at levels of 0, 5 and 10%. The 0% DGRC diet was the control. The experimental diets were formulated on iso-caloric and iso-nitrogenous principles in line with the nutritional requirements for growing broiler birds. Experimental birds were first fed on a common starter broiler diet comprising of 21% CP and 3100 Kcal/kg feed from 0 to 21 days of age; thereafter the birds (21-42 days) were allotted to the experimental treatments in a completely randomized design (CRD) with three replications. A cage with 10 birds was the experimental unit. Experimental diets were offered in the morning and evening, water was provided *ad lib*. Feed offered and leftovers were weighed daily, and body weight changes were recorded on a weekly basis. The results showed that birds on the 5% diet had significantly (Linear, Quadratic $P<0.05$) higher final body weights (FBWs), average daily gain (ADG) and better feed conversion ratio (FCR) compared to those o on diets with 0 and 10% DGRC. Apparent and ileal digestibility of nutrients was improved with incorporation of dried goat rumen contents in the diets. Sensory analysis showed that meat from birds on 5% DGRC diet had ($P<0.05$) more oil content and softer meat across diets. It is concluded that, use of dried goat rumen contents (DGRC) in broiler diets improves growth performance and organoleptic qualities of broiler chicken meat.

Key words: Digestibility, growth performance, rumen contents, sensory attributes.

INTRODUCTION

In Uganda, many commercial poultry farmers are grappling with feed related costs that have pushed

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several of them out of the poultry business. In a bid to remain competitive in the poultry industry, poultry farmers near slaughter houses mostly in the urban settings have ventured into the use of rumen contents as alternative protein source to fish meal (FM) which is a more expensive feed ingredient (Van Huis et al., 2013). Fish meal is a predominant principal source of animal protein in animal feed industry due to its higher biological value and essential amino acids profile (Shahid and Talat, 2005) has become a target of adulteration by many feed dealers. This is in a bid by feed dealers to make more profits at the expense of the poultry farmers. Eventually, the production of birds has been poor and poultry farmers' returns to investment have also decreased with many failing to break even as a consequence of rampant feed ingredient adulteration. The inclusion of rumen contents in poultry diets comes as not only a sustainability strategy by poultry farmers (Vahid et al., 2017; Sugiharto, 2019), but also pivotal to the safe disposal of abattoir wastes through recycling (Dairo et al., 2005; Esonu et al., 2006). However, rumen content use in poultry diets is done with limited information in regard to processing, and level of use in poultry diets which further compromises production performance of the birds. Despite having relatively good crude protein (CP) and minerals levels, energy and vitamins especially vitamin B complex (Agbabiaka et al., 2012), rumen contents contain high dietary fiber which affects dietary energy levels. More so, rumen contents tend to have a repulsive smell and an inherent color which affects its acceptability by the animals. Previous studies have reported variations in rumen content composition. For instance, Ravindra et al. (2017) reported that use of buffalo rumen content in poultry diet contain a crude protein (CP) of 8.5% and crude fiber (CF) of 34.1%. On the other hand, a study by Sakaba et al. (2017) found that cattle rumen content contained CF of 48.1% and CP of 14.73%, whereas Sheep rumen contents were found to contain CF and CP of 48.7 and 15.5% respectively. All these reports indicate nutritional variability of rumen content with respect to animal type. Moreover, during the dry season, animals tend to consume forages that are coarse and high in fiber but with little nutritional composition which results in rumen content of high crude fiber (CF), low crude protein (CP) and consequently, of low nutritional value to poultry. However, small ruminants and particularly goats have a higher degree of quality forage selection than grazing large ruminants (Taylor and Kotman, 1990). Goats tend to go for tender and more nutritious plant portions of plants (low lignification, high CP and low tannin) which translates to finer rumen contents with less fiber and of potentially high nutritional value to chickens. The objective of the present study was to improve the utilization of rumen contents in poultry through evaluation of dried goat rumen content (DGRC) as a protein substitute to fish meal on broiler performance, carcass characteristics and sensory attributes.

MATERIALS AND METHODS

Experimental site

The study was conducted at Tatton Agriculture Park (TAP), Egerton University, Njoro, Kenya. The farm lies on a latitude of 0° 23' south, longitude 35° 35' East and an altitude of 2238 m above sea level and receives a bimodal mean annual rainfall of 1000-1200 mm. Long rains are received between April and August and short rains between October and December. According to Egerton University weather station, mean annual temperatures range between 10 and 22°C (Egerton University, Civil and Environmental Engineering Department).

Rumen content collection and processing

Goat rumen contents were collected from Kampala city abattoirs immediately following slaughter during the wet season of September- January 2018 and March to April 2019. The rumen content was then sun dried to a moisture content of about 12%, bagged stored. Thereafter it was milled in a hammer mill through a 1.5 mm screen.

Proximate analysis

Ground rumen content samples were analyzed for dry matter (DM), nitrogen (N), gross energy (GE), ether extract (EE), calcium (Ca), phosphorus (P), crude fiber (CF), neutral detergent fiber (NDF), and acid detergent fiber (ADF) (AOAC, 2005). Dry matter was determined according to AOAC International (2005) standard procedures. Nitrogen was determined by Kjedhal's method (AOAC International, 2005, method 968.06) using a CNS-2000 carbon, nitrogen, and sulfur analyzer (Leco Corporation, St. Joseph, MI). The CP values were determined by multiplying the assayed N values by 6.25. GE was determined using an adiabatic bomb calorimeter (Gallenkamp, London, UK), standardized with benzoic acid. Ether extract content was determined following Soxhlet extraction procedure. Calcium (Ca) and phosphorus (P) were determined using atomic absorption spectrophotometer. Nitrogen free extract (NFE) was calculated by subtracting the sum of % ash, % crude ether extract (EE), % crude fibre (CF) and % crude protein (CP) from 100.

$$\%\text{NFE} = 100 - (\%Ash + \%CF + \%EE + \%CP)$$

Amino acid (AA) analysis of the feed ingredients

Amino acid analysis was performed at Laboratory of Gastrointestinal Microbiology, National Center for International Research on Animal Gut Nutrition, Nanjing Agricultural University. The protein samples were hydrolyzed in gas phase using 6 M HCl at 115°C for 24 h. The liberated amino acids were converted into phenylthiocarbamyl derivatives and analyzed by high-pressure liquid chromatography (HPLC) on a PicoTag 3.9 × 150 mm column (Waters, Milford, MA, USA).

Dietary formulations

The ingredients used in formulating experimental diets are shown in Table 1. In the diets, dried goat rumen content (DGRD) substituted fish meal at levels of 0, 5 and 10%. The diet with 0% dried goat rumen contents was the control. The experimental diets were

Table 1. Dietary composition of broiler finisher diets (22-42 days).

Ingredients	Dietary treatment		
	T1	T2	T3
DGRC	0.0	5.0	10.0
BM	59.0	67.0	68.2
WP	17.1	7.1	2.0
FM	10.0	8.0	6.0
SBM	12	11	11.9
DCP	0.9	0.9	0.9
Lime stone	0.2	0.2	0.2
Salt	0.3	0.3	0.3
*Vitamin premix	0.5	0.5	0.5
Total/kg	**100**	**100**	**100**
Calculated (%)			
DM	89.6	89.8	90.9
CP	20.6	20.8	20.2
Ca	0.5	0.5	0.5
P	0.6	0.6	0.6
CF	4.2	4.9	5.3
ME Kcal/Kg	3141	3112	3100

*To supply Vitamins A 12000000 iu; D3 2500000 iu; E 20000 mg; K3 2000 mg; B1 2000 mg; B2 5000 mg; B6 4000 mg; B12 15 mg; Niacin 30000 mg; Pantothenic acid 11000 mg; Folic acid 1500 mg; Biotin 60 mg; Choline chloride 220000 mg; Antioxidant 1250 mg; Mn 50000 mg; Zn 40000 mg; Fe 20000 mg; Cu 3000 mg; I 1000 mg; Se 200 mg; Co 200 mg. [1] DGRC: dried goat rumen contents; BM: broken maize; WP: wheat pollard; SB: soybean meal; FM: Fish meal; DM: dry matter; CP: crude protein; CF: crude fibre; Ca: calcium; P: phosphorous; ME: metabolisable energy.

iso-caloric (3100 Kcal/Kg) and iso-nitrogeneous (20% CP) and contained equal levels of calcium (Ca), phosphorus (P), sulphur amino acids, lysine and sodium in line with the dietary nutritional requirement for growing broiler birds (NRC, 2001).

Management of birds, feeding and performance measurements

Day old broiler chicks were purchased from KENCHICK, a Kenyan company that specializes in poultry related businesses. The chicks were brooded for 21 days under a common starter diet; after which they were weighed and allotted to 9 cages (10 chicks per cage) such that the mean bird weight per cage was similar (0.52±0.01 g). The three dietary treatments were then randomly allotted to 9 cages in a completely randomized design (CRD) with three replicates. Birds were allocated a space of 530 and 640 cm^2 in the brooder and grower cages respectively. Feed and clean water were provided *ad libitum* basis during the entire experimental period. Vaccination against major diseases like Gumboro, fowl pox and Newcastle were carried out in line with the recommended veterinary vaccination schedule. Experimental diets were offered to the birds in the finisher stage starting on the 22nd day, as to allow time for the bird's caecum to develop fully to size capable of handling fiber in the experimental diets. Body weight (BW) was taken on a weekly basis while feed intake (FI) on a daily basis throughout the experimental period. Mortalities were recorded whenever they occurred. Average daily gain (ADG) and feed conversion ratio (FCR) were calculated by dividing the change in weight and total feed intake by weight gain of live birds in a week respectively.

Digestibility of experimental diets

From the 35th to 39th, feed intake and total faecal output were measured per cage over a period of 4 consecutive days for determination of nutrient retention and apparent metabolizable energy (AME). On the 42nd day, 12 birds per treatment were euthanized by intracardial injection of sodium pentobarbitone and contents of the lower half of the ileum were expressed by gentle flushing with distilled water. Digesta from birds within a cage was pooled, resulting in 3 samples per dietary treatment; the samples were frozen immediately after collection and stored for analysis.

Sample chemical analysis

The samples of excreta and ileal contents were freeze dried. Samples of diets, ileal contents and excreta were ground to pass through a 0.5-mm sieve and stored in airtight plastic containers at −4°C until chemical analyses.

Determination of apparent metabolisable energy and ileal digestibility

Apparent metabolizable energy (AME) values of the diets were calculated from the equation below

$$AME\ feed \frac{MJ}{Kg} = \frac{(Feed\ intake\ x\ GE\ diet) - (Excreta\ out\ put\ x\ GE\ excreta)}{Feed\ intake}$$

Where GE is given in kilocalories per kilogram, and feed intake and faecal output in kilograms DM per day. Nitrogen-corrected AME was determined by correction for zero nitrogen retention by simple multiplication with 8.22 kcal per gram nitrogen retained in the body as described by Hill and Anderson (1958).

The apparent ileal digestibility of DM, nutrients (CP and fat), and GE was calculated following the formula below, Chromium III Oxide external marker ratio in the diet and ileal digesta:

$$\text{Apparent ileal digestibility(\%)} = \frac{\left(\frac{NT}{indicator}\right) diet - \left(\frac{NT}{Indicator}\right) ileal\ digesta}{\left(\frac{NT}{Indicator}\right) diet} x\ 100$$

Where, (NT/Indicator) diet = ratio of component and indicator in the diet, and (NT/Indicator) ileal content = ratio of component and indicator in ileal contents. Component can be DM, CP, fat, or GE.

Apparent total tract retention of DM, EE, CP, calcium, phosphorus, and CF were calculated as follows:

$$\text{Retention \%} = \frac{(Feed\ Intake\ x\ Component\ in\ diet) - (\text{Excreta out put x Component in excreta})}{(Feed\ Intake\ x\ Component\ in\ diet)} x\ 100$$

Components are DM, EE, CP, calcium, phosphorus, CF. Feed intake and excreta output are given in kilograms per day and components as a percentage (Adeola et al., 2008).

Slaughtering procedure

At the 42nd day, 4 birds per treatment per replicate were numbered randomly, selected, weighed, and slaughtered in accordance with the animal welfare law (Anderson, 2004). Prior to slaughter, feed was withdrawn for 12 h but water was provided *adlibitum* basis in order to clear the digestive tract. The birds were slaughtered following the cervical dislocation method, then plucked and eviscerated. Breast and thigh meat were used for sensory evaluation.

Sensory evaluation of broiler meat samples

Cooked meat samples (breast and thigh) were evaluated for sensory attributes at the Department of Dairy, Food Science and Technology (DAFTEC), Egerton University. A commercial broiler from a local supermarket was purchased and used as a reference sample during orientation and evaluation. A trained 20-member panel (instructors and undergraduate and post graduates students) was used to evaluate the meat samples using a 15-cm line scale. The panelists were trained in sensory evaluation according to Stone and Sidel (2004). During the orientation sessions, the panel agreed on the attributes to use for evaluation, evaluated several samples, and rated the intensities of the reference sample (agreed upon by consensus by the panel). The reference was used as a warm-up sample and was provided to the panelists with its intensities during the testing sessions. Boiled chicken meat was prepared following deboning and cutting into small pieces of approximately 2 x 2 cm. Meat from each carcass was cooked separately according to the treatments. The meat pieces were put into the cooking pot and water was added to cover it. The cooking lasted for 50 min. The cooked meat pieces were then presented for descriptive sensory analysis. Samples were randomized according to the diet of the chicken and then by meat type (breast meat or thigh). Each panelist was provided with 6 pieces on a white sensory evaluation plates labeled with 3-digit blinding codes. Cooked samples were evaluated for color, glossiness, juiciness, texture, chewiness, fattiness, chicken flavor, and overall quality. Water was provided for cleansing and rinsing the palate between samples. The panelists recorded attributes intensities on the scale by placing a slash perpendicular to the line at the point that best described the attribute. The numerical intensity was measured in centimeters with a ruler from the left-hand side of the scale.

Data analysis

Data for growth, digestibility and carcass data were first subjected to normality and homogeneity of variance tests and thereafter were analyzed using the GLM procedures of SAS (2010) as a completely randomized design (CRD). Treatment effects were determined with orthogonal contrasts arrangement. Separation of means where significant differences occurred was done using Tukey's test at $P \leq 0.05$. The sensory data did not meet the conditions for parametric statistical tests and therefore non-parametric statistical tests were applied. The differences between groups for sensory data were tested with Kruskal-Wallis test.

RESULTS

Proximate analysis of feed ingredients and experimental diets

Table 2 shows the results of the laboratory analysis of the feed ingredients used in the formulation of experimental diets. Dried goat rumen contents (DGRC) had lower crude protein (CP) and Metabolizable energy (ME) compared to rest of the ingredients used; however, DGRC was higher in crude fiber (CF) and Phosphorus (P). Amino acid (AA) profile and dried goat rumen content (DGRC) were comparable to wheat pollard (WP). Overall, total amino acids (TAA) were higher for fish meal (FM) followed by broken maize (BM).

Proximate composition of experimental diets

Chemical composition of the experimental diets is shown in Table 3. Dry matter (DM), Crude protein (CP) and ether extract (EE) was similar across diets. Crude fiber (CF) in the dietary treatments differed slightly and was higher in diet with 10% dried goat rumen content inclusion levels (DGRC). Despite the slight disparities in the CF content of the diets, CF of the diets was within the range (2-5%) for optimum broiler performance as reported by NRC. Metabolizable Energy (ME) of the dietary treatments ranged between 31500-3200 Kcal/kg feed.

Effects of DGRC inclusion levels on apparent and ileal nutrient digestibility of diets in broilers

Apparent and ileal nutrient digestibility for experimental diets in broiler chickens is shown in Table 4. The results in the present study indicated that inclusion of DGRC levels in broiler diets had a significant ($P<0.05$) effect on apparent and ileal digestibility in broiler chickens. The

Table 2. Proximate composition of feed ingredients used in experimental dietary formulations**.**

Composition (%)	BM	WP	SBM	FM	DGRC
DM	89.51	86.00	89.23	93.10	97.3
CP	10.64	10.61	44.41	58.21	16.2
CF	1.95	7.43	3.51	12.01	20.7
Ca	0.01	0.001	0.20	2.97	1.70
P	0.23	0.06	0.65	2.62	3.80
ME	3400.01	2900.32	2800.41	3290.03	1190.16
Amino acids					
Ala	0.13	0.10	0.12	0.18	0.09
Arg	0.11	0.07	0.07	0.10	0.09
Asn	0.00	0.00	0.00	0.00	0.00
Asp	0.16	0.14	0.18	0.18	0.18
Gln	0.01	0.00	0.00	0.01	0.00
Glu	0.27	0.08	0.15	0.27	0.06
Gly	0.12	0.07	0.04	0.12	0.05
His	0.00	0.02	0.02	0.00	0.02
Ile	1.98	1.81	1.86	2.01	1.76
Leu	0.09	0.03	0.07	0.12	0.00
Lys	0.11	0.06	0.09	0.15	0.07
Met	0.09	0.07	0.04	0.15	0.06
Phe	0.03	0.03	0.03	0.05	0.03
Ser	0.00	0.00	0.00	0.00	0.00
Thr	0.11	0.07	0.00	0.14	0.03
Trp	0.05	0.05	0.03	0.05	0.05
Tyr	0.09	0.09	0.09	0.09	0.09
Val	0.12	0.09	0.11	0.15	0.09
Total AA	3.47	2.77	2.90	3.79	2.66

[1] BP: broken maize; WP: wheat pollard; SB: soybean meal; FM: Fish meal; DGRC: dried goat rumen contents; DM: dry matter; CP: crude protein; CF: crude fiber; NDF: neutral detergent fiber; EE: ether extract; Ca: calcium; P: phosphorous; ME: metabolisable energy; AA: Amino acids Ala: Alanine; Arg: Arginine; Asn: Asparagine; Asp: Aspartic acid; Gln: Glutamine; Glu:Glutamic acid; Gly:Glycine; His:Histidine ; Ile: Isoleucine; Leu: Leucine; Lys: Lysine; Met: Methionine; Phe: Phenylalanine; Ser: Serine; Thr: Threonine; Trp: Tryptophan; Tyr: Tyrosine; Val: Valine.

Table 3. Chemical composition of the experimental diets (laboratory analysis).

Parameter	Dietary treatment		
	T1	T2	T3
DM%	89.73 ±0.26	87.11± 0.26	87.99 ±0.26
CP%	21.01 ±3.14	21.09± 3.14	21.11 ±3.14
EE%	7.00 ±0.01	8.00 ±0.01	8.00 ± 0.01
CF%	2.9 ±0.02	3.50 ±0.02	4.50 ±0.02
Ash%	5.25 ±0.22	5.05 ±0.22	4.77± 0.22
Ca%	1.98 ±0.07	1.90±0.07	1.80±0.07
P%	0.36 ±0.54	1.18 ±0.54	0.29± 0.54
NFE%	64.74 ±1.74	61.20 ± 1.74	66.56 ± 1.74
ME Kcal/Kg	3275.14 ±7.17	3242.06 ± 7.17	3236.75 ± 7.17

DM: dry matter; CP: crude protein; CF: crude fiber; NDF: EE: ether extract; Ca: calcium; P: phosphorous; NFE Neutral free extract; ME: metabolisable energy. Values presented in means and standard error of means (Means±SE); T1=0% DGRC; T2=5% DGRC; T1=10% DGRC.

Table 4. Apparent nutrient and ileal digestibility of diets containing DGRC in broilers.

Apparent nutrient digestibility	Dietary treatment		
	T1	T2	T3
DM	71.27[b]	93.92[a]	71.27[b]
CP	60.31[c]	89.67[a]	85.29[b]
CF	59.14[c]	71.80[a]	67.82[b]
EE	64.34[c]	87.42[a]	77.60[b]
Ca	74.04[c]	86.72[a]	80.12[b]
P	69.44[b]	75.53[a]	74.92[a]
Ash	60.35[c]	82.35[a]	78.61[b]
NFE	82.2[c]	89.97[a]	86.06[b]
ME	78.89[c]	92.22[b]	81.31[b]
SEM	0.63	0.88	2.48
Linear	0.9655	0.0003	0.0898
Quadratic	0.1628	<0.0001	0.0012
Apparent ileal digestibility			
DM	79.94[b]	91.22[a]	68.22[c]
CP	79.17[b]	91.85[a]	68.26[c]
CF	65.23[c]	90.37[a]	76.48[b]
EE	70.02[b]	79.42[a]	67.60[c]
Ca	76.69[b]	92.56[a]	61.25b[c]
P	77.68[a]	77.83[a]	62.06[b]
Ash	83.55[a]	83.57[a]	72.47[b]
NFE	76.41[ab]	78.22[a]	69.86[b]
ME	81.13[a]	83.35[a]	72.00[b]
SEM	2.11	2.75	2.123
Linear	0.0234	0.0617	0.1949
Quadratic	0.0040	0.4498	0.0433

[abc]Means with different superscript within row differ significantly (P<0.05). BP: broken maize; WP: wheat pollard; SB: soybean meal; FM: Fish meal; DGRC: dried goat rumen contents; DM: dry matter; CP: crude protein; CF: crude fiber; NDF: neutral detergent fiber; EE: ether extract; Ca: calcium; P: phosphorous; ME: metabolisable energy; SEM: Standard error of the mean.

experimental diets with 5% DGRC levels had the highest apparent digestibility coefficients for DM,CP,CF, EE, Ca, Ash and NFE followed by diets with 10% DGRC levels with exception P and ME which were comparable. The diets without DGRC had the lowest apparent digestibility in those parameters compared with other studied experimental diets with DGRC. Generally, the results showed an increasing trend of apparent digestibility coefficients for all nutrients studied nutrients with inclusion of 5% DGRC level in the experimental diets but showed a decreasing trend with incorporation with 10% DGRC level in the diet with exception of P and ME. In addition, the results indicated that diets with 5% DGRC inclusion level in the experimental diets had the highest ileal digestibility whereas those diets with 10% DGRC inclusion level had lowest ileal digestibility for DM, CP, CF, EE, Ca and NFE. Therefore, the diets with 5% DGRC level in the experimental diets showed an increasing trend of ileal digestibility for DM, CP, CF, EE, Ca and NFE but inclusion of 10% DGRC level in diets showed a decreasing trend of ileal digestibility compared to those diets with 5% DGRC level though had higher digestibility coefficients than control diets.

Performance of broiler chickens fed dried goat rumen content

The performance of birds fed diets with dried goat rumen content is shown in Table 5. Incorporation of dried goat rumen contents in broiler diets lead to improved growth performance of birds. Birds on 5% dried goat rumen content (DGRC) had a significantly higher average final body weight (Linear, Quadratic $p<0.05$), average daily gain (ADG) (Quadratic, $p<0.05$) and a lower average daily feed intake (ADFI) compared to the control diet (Table 5). Similarly, the feed conversion ratio (FCR) was significantly lower (Linear, Quadratic, $p<0.05$) for the

Table 5. Performance of broiler chickens fed experimental diets.

Parameter (n=90)	Level of DGRC			SEM	*p*-value	
	0%	5%	10%		Linear	Quadratic
AIBW (kg/bird/day)	0.52[a]	0.52[a]	0.52[a]	0.01	0.9601	0.9080
AFBW (kg/bird/day)	1.59[c]	1.84[a]	1.64[b]	0.02	0.0031	<0.0001
ADFI (g/bird/day)	115.81[a]	88.94[b]	87.40[c]	0.45	<.0001	<0.0001
ADG (g/bird/day)	52.76[b]	60.08[a]	52.29[b]	0.23	0.1636	<0.0001
FCR	2.19[a]	1.49[c]	1.67[b]	0.05	<.0001	<0.0001

[abc]Means with different upper case letters within a row differ significantly at $P<0.05$; DGRC dried goat rumen content; AIBW average initial body weight; AFBW average final body weight; ADFI average daily feed intake; ADG average daily gain; FCR feed conversion ratio SEM standard error of the mean.

birds fed on diets containing 5% DGRC across diets than birds on the control diet (0% DGRC). Average daily feed intake (ADFI) was significantly higher (Linear, Quadratic $p<0.05$) for birds fed on 0% dried goat rumen content (DGRC) compared to other dietary treatments. However, as the level of DGRC increased in the diet, average daily feed intake (ADFI) of birds decreased. Despite the higher average daily feed intake (ADFI) exhibited by the birds fed on 0% dried goat rumen content (DGRC) inclusion level, the birds showed lower average daily weight gain (ADG). Although there were differences in average daily feed intake (ADFI) exhibited by the birds on different dietary treatments, DGRC in the experimental diets was readily accepted by the birds across the two treatments (5 and 10%) inclusion levels. No death was registered among birds across the three dietary treatments.

Effect of dried goat rumen contents (DGRC) on sensory characteristics of broiler meat

Table 6 shows the effects of incorporating dried goat rumen contents (DGRC) in broiler diets on broiler meat sensory characteristics. The results showed that inclusion of DGRC in broiler diets affected oiliness, wetness, hardness, juiciness and ease of swallow of broiler meat. Birds fed diets with 5% dried goat rumen content had meat with the highest ($P<0.05$) oiliness followed by those fed diets with 10% dried goat rumen whereas those birds fed diets with 0% (control) dried goat rumen had the significantly ($P<0.05$) lowest. However, the present study (Table 6) revealed that inclusion of DGRC in broiler diets had no significant ($P>0.05$) effect on color, flavor, bitterness, sweetness, fishy flavor, springiness, fatty mouth feel, ease of swallow, tooth pack and fibrousness of broiler chicken meat.

DISCUSSION

Chemical composition of feed ingredients and experimental diets

The higher crude fiber (CF) and phosphorus (P) exhibited by diets with dried goat rumen contents is in line with the findings of Djordjevic et al. (2006). Dry matter (DM), crude protein (CP), calcium (Ca) and phosphorus (P) values of DGRC were higher than those reported by Efrem et al. (2016). This may be due to nutritional differences with respect to season and the type of animal from which the rumen contents were gotten from. In this study, goat rumen contents were collected from the abattoir during the wet season, and thus, the forages eaten by the goats prior to slaughter may have been young and tender with high concentration of minerals (Agbabiaka et al., 2012). Goats are browsers and concentrate selectors; they tend to go for tender leaves and grasses that are more nutritious resulting in their rumen content being finer, less fibrous and more nutritious than that of large ruminants (bulky feeders). This may further explain why goat rumen content was lower crude fiber (CF) in relation to results of Efrem et al. (2016). The composition of rumen contents is also influenced by pre-slaughtering conditions exposed to the animals and the length of holding period between feeding and slaughter (Abouheif et al., 1999).

Despite the experimental diets being formulated to meet the nutritional requirements for growing birds at isocaloric and iso-nitrogenous principles (Table 3), there were differences in fiber contents of the diets as a result of dried goat rumen content (DGRC) incorporation. Even though the fiber content of the diet with 10% dried goat rumen content (DGRC) inclusion level (Table 3) was higher, it was within the limit (2-5%) to elicit normal growth responses of the birds. Several authors have reported that rumen contents contain high fiber content which tend to increase the total fiber of the diets (Esonu et al., 2004; Khan et al., 2014).

Effect of DGRC inclusion levels in broiler diets on nutrient digestibility

Improvements in nutrient digestibility leads to increased nutrient availability which eventually improves the performance of birds. In this study, incorporation of dried goat rumen contents (DGRC) at 5% improved the digestibility (Table 4) of crude fibre (CF), calcium (Ca) and phosphorous (P). This implied that, there is a limit to

Table 6. Effect of dried goat rumen contents (DGRC) diets on sensory characteristics of broiler meat.

Attribute	Mean Rank			P-value
	T1	T2	T3	
Color	126.98	134.99	135.52	0.993
Color uniformity	133.45	124.03	138.43	0.446
Flavor	118.27	141.32	137.91	0.097
Fishy smell	143.65	131.54	122.31	0.177
Umami	125.07	131.19	141.23	0.366
Bitterness	137.64	132.41	127.45	0.675
Sweatiness	123.13	142.58	131.79	0.238
Oiliness	109.19	144.34	143.98	0.002*
Wetness	107.31	146.81	142.00	0.001*
Springiness	134.99	132.17	130.34	0.94
Hardness	153.60	122.32	121.57	0.006*
Juiciness	115.45	146.41	135.64	0.025*
Fibrousness	147.54	123.60	125.04	0.066
Chew count	143.35	119.53	131.62	0.144
Sustained Juiciness	123.99	137.79	135.72	0.433
Easy of swallow	116.69	144.97	134.37	0.045*
Fatty feel	117.96	140.09	138.04	0.103
Tooth pack	143.38	123.70	128.83	0.206

*Mean rank significant at (P<0.05); T1= 0% dried goat rumen contents (DGRC); T2=5% dried goat rumen contents (DGRC); T3= dried goat rumen contents (DGRC)

which dried goat rumen contents can be incorporated in diets for growing birds beyond which digestibility of nutrients becomes compromised. The apparent ileal digestibility coefficients (Table 4) revealed the same trend; birds on 5% dried goat rumen content (DGRC) diet had better digestibility coefficients in relation to dry matter (DM), crude protein (CP) and phosphorus than those on 0% DGRC and 10% DGRC diets. However, despite the differences existing in apparent ileal digestibility (AID), the coefficients seemed to have been over estimated by the model. This result concurs with the findings of Garcia et al. (2007).

Effects of inclusion of DGRC in broiler diets on performance of broiler chickens

The improved growth performance of broilers on diets with DGRC compared to those on control diets (Table 5) observed in the present study is in agreement with the the results of Esonu et al. (2006) who reported a general increase in growth rates of birds as rumen contents were increased in the diets. However, the significant decrease in average daily feed intake (ADFI) of birds with increase in DGRC in the diets may be attributed to increase in dietary fiber content (Ubua et al., 2019) and more so, to the unpleasant smell of rumen contents. Dietary fiber limits feed intake (FI) more especially in young birds because their gastrointestinal tract (GIT) cannot digest fiber more easily (Ubua et al., 2019). As the level of DGRC increased in the diets, this could have led to a commensurate increase of unpleasant smell in the diets which could have eventually translated into reduced feed intake by the birds (Odonsi, 2003; Said et al., 2015). Despite the reduced average feed daily intake (AFDI) exhibited by the birds fed diets with DGRC, their growth performance was not compromised. Birds on 5% DGRC diet had better body weights (BWs) with across diets. This may be partly attributed to better feed utilization by the birds (Table 4) and more so, rumen contents are largely comprised of partially digested forages with appreciable quantities of microbial protein, tnnins, volatile fatty acids (VFAs) and a vast array of minerals which could have promoted good chick growth and more so, improved health gut development (Rodriguez et al., 2012; Sugiarto et al., 2014; Alagbe, 2017; Hidanah et al., 2018; Sebola et al., 2019). Even though the diets with DGRC were high in fiber, this could have been within the limits (2-5%) as not to compromise nutrient availability and retention by the birds.

Several studies have reported a decline in performance of birds as the levels of rumen content (RC) was increased in the diets (Colette et al., 2013; Elfaki et al., 2015; Tesfaye et al., 2013). In this study, even though the growth performance of birds declined significantly as the level of dried goat rumen content (DGRC) in the diets was increased up to 10%, this did not differ from the control diet with 0% DGRC. This indicates that, even the

10% DGRC diet could be effective in replacing the control diet (0% inclusion of DGRC) without compromising the bird's performance and at even a better feed conversion ratio (FCR). The lower FCR exhibited by the birds fed on diets with DGRC is in line with the findings of Makinde et al. (2008). These results are handy and comes at a time when poultry farmers are grappling with adulteration of feed ingredients especially those of animal protein origin (fish meal) which are more expensive (Shahid and Talat, 2005; Mwesigwa et al., 2013; Mohanta et al., 2013; Vahid et al., 2017). Rumen contents are less expensive and readily available at most slaughter houses. Therefore, efficient utilization as livestock feed ingredients would not only save farmers a great deal of costs but also safeguard the environment from pollution (Katongole et al., 2009). The mechanisms through which DGRC based diets improved the performance of the birds cannot be fully elucidated by the collected data. However, digestive and absorptive capacity of the birds could have been increased, hence encouraging a greater flow and absorption of nutrients in the small intestines.

Effect of dried goat rumen contents (DGRC) diets on sensory characteristics of broiler meat

The appearance of meat in terms of texture, juiciness, wateriness, firmness, tenderness, odor and flavor are the most important meat factors that determine judgment by consumers before and after purchasing a meat product (Nasir et al., 2017). In the present study, Juiciness, oiliness, flavor and hardness of broiler meat were improved by the addition of dried goat rumen contents (DGRC) in the diets (Table 6). These results implies that inclusion of DGRC in broiler diets imparted fat which may have influenced taste, juiciness and flavor in meat and that could increase acceptability of meat to most consumers (Nasir et al., 2017 Cofrades et al., 2000). Further, the results suggested that inclusion of DGRC in broiler diets increased oiliness to meat and that led to tender meat that could increase acceptability of meat to most consumers. The degree of oiliness of meat is positively correlated with meat softness (de lavergne et al., 2015; Damian et al., 2016). This phenomenon partly explains why broiler meat from birds fed on DGRC content in this study had more tender meat (Table 6) compared with meat from the control group. These results suggest that inclusion of DGRC in the broiler diets could improve sensory characteristics and tenderness of meat, and eventually improve its market demand.

In the present study, inclusion of DGRC in the diet had no significant effect on general color of the meat. These results suggested that DGRC had not influenced myoglobin activities for storing and delivering oxygen in the muscle (Joo et al., 2013). However, in the present study, it was revealed that inclusion of DGRC in the broiler diets had an influence on skin color at the time of slaughter. The birds fed diets incorporated with DGRC had yellowish skin color compared with their counterparts fed the control diets. These results could be associated with carotenoid deposition in the skin, resulting primarily from xanthophylls in the DGRC and that could be of significance to consumer's meat acceptability. Yellow color or appearance of the meat is the most important factor of meat consumer's acceptability. Most of consumers often link yellow color with freshness and nutritional value (Joo et al., 2013). The results suggested that inclusion of DGRC in broiler diets could produce meat with attractive color to consumers and eventually increase its market demand.

CONCLUSION

From the results, it can be concluded that inclusion of DGRC in broiler diets improved nutrient digestibility coefficients for proximate components, minerals and energy contents of broiler diets, suggesting its use could improve utilization and feeding value of broiler diets. It also improved growth performance, feed intake and feed conversion ratio, suggesting that its use could improve broiler performance. Improved sensory characteristics, tenderness and color of broiler meat suggested that DGRC use could improve consumers' acceptability and eventually market demand of broiler chicken meat.

REASEARCH APPROVAL

Permission to carry out this research was granted by the National Commission for Science and Technology of Kenya, under permit No: NACOSTI/P/19/96187/28085. Ethical of approval was granted by Institute of Primate Research of Kenya under Reference No. ISERC/02/19

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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