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Effect of concentrate supplementation and season on apparent digestibility and growth performance of sheep in smallholder production system

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Abstract

The effect of concentrate feed supplementation, healthcare and season on dry matter and nitrogen apparent digestibility and growth performance of sheep were investigated in the smallholder production system. A total of 819 sheep belonging to 36 smallholder farmers were studied. Animals in each pen were randomly assigned to one of 2 feeding regimes. The first regime (control) was grazing and crop residues supplementation (75 g DM/d). In the second regime, sheep were treated as in first and given an additional package of concentrate feed (180 g DM/d) plus orthodox prophylactic and curative healthcare. Dry matter and nitrogen apparent digestibility and growth performance of animals were determined seasonally. The dry matter intake among animals on concentrate supplementation was higher ($P<0.05$) than those on control (608 vs. 515 g DM/d) but the faecal output was similar. Seasonally, DM intake was found highest during the early wet season (679 g DM/d) and lowest in the main wet season (397 g DM/d). Nitrogen intake was significantly affected by concentrate supplementation (11 vs. 8 g DM/d for concentrate supplemented and control groups respectively). Season significantly affected dry matter and nitrogen digestibility with the early wet season having the highest digestibility. The concentrate supplementation and healthcare provision package improved feed digestibility and increased ADG of animals from 19 g/d to 34 g/d in the smallholder production system.

Keywords: *Dry matter; feed resources, nitrogen, season, smallholder farmers*

INTRODUCTION

Livestock production is a major source of livelihood for many farmers next to crops in developing countries (FAO, 2014). It is, however, constrained by many factors such as climate variability,

urbanization and competing land use (Thornton, 2010). These factors reduce feed availability in the production system. In Sub-Saharan Africa, over 70% of animal products are produced by smallholder farmers (FAO, 2014). These farmers, however, depend heavily on the limited natural pasture and crop residues as sources of feed. This feed limitation is a major constraint both in the dry and wet season as the accessibility of herbage to animals is limited during cropping (wet) season in some communities due to compound farming (Awuma, 2012).
Another factor limiting productivity is decreasing quality of natural pasture with change in seasons from wet to dry season. In Ghana, FAO (2006) reported that the protein content of natural pasture is high in the wet season (8 – 12%) and low in the dry season (2 to 4%). Diogo *et al.* (2010) stated that availability of information on the nutritional quality of existing feed resources throughout the year is a key resource for efficient nutrient utilization and could help farmers meet the nutritional requirement of animals to improve productivity.

Powell *et al*. (1995) stated that nutrient use efficiency in crop-livestock production systems is best promoted through intensification and integration of the production systems. To sustain intensification, it is necessary to harness the complementary benefits inherent in crop-livestock systems. The core issue in crop-livestock integration is nutrient use efficiency that directly affects production cost and profitability. Specific pathways that could intensify nutrient use in ruminant production include increased biomass production and conservation, improving feed digestibility through optimum supplementation with good quality concentrate feed and crop residues (Diogo *et al*., 2010; Agyemang, 2012) and estimation of collectable manure (faecal droppings) for improving soil fertility to sustain crops yield.

In ruminants, nutrient intake and digestibility are influenced by many factors (Powell *et al*., 1996). For instance, the nutrient content of available feed greatly influences intake, digestibility and faecal nutrient content (Powell *et al*., 1995). Nitrogen (N) is one of the major nutrients that impact greatly on the productivity of the crop-livestock production system. The intake of N in ruminants is influenced by seasonality due to changes in forage composition and diversity (Powell *et al*., 1996). Schlecht *et al*. (1995) reported 2.9% increase in daily N intake from 1.3% during the late dry season to 4.2% in the early wet season of total dry matter (DM) intake of cattle in Mali. Also, N intake and faecal output are influenced by feeding regime and increase with legume forage intake and cereal bran supplementation (Powell *et al*., 1995; Ayantunde *et al*., 2008). Faecal nitrogen content of sheep has been reported to increase when fed browses than crop residues (Reed *et al*., 1990; Somda *et al*., 1993). There is however inadequate information on on-farm apparent digestibility of DM and N in sheep under smallholder production system in different seasons of the year in northern Ghana. This work was conducted to estimate the effect of concentrate feed supplementation, healthcare provision and season on apparent digestibility of DM and N and sheep growth performance in the smallholder production system.

MATERIALS AND METHODS

Study area

The study was conducted in the formal three administrative regions of northern Ghana which previously included Northern Region, Upper East Region and Upper West Region. The three regions are located within latitude 9. 38" S and 10. 24" N and longitude 2. 61" W and 0. 84" E in the Guinea Savanna ecological zone (Konlan *et al*., 2017). Annual rainfall ranges from 1000 to1100 mm. The rainfall pattern is unimodal and begins in April and ends in October (MoFA, 2011; FAO, 2006). The vegetation consists of short, deciduous, widely spaced, fire-resistant trees and shrubs, which do not form a closed canopy. The ground landscape is covered by grass, forbs, and shrubs of varying heights in the wet season and mostly bare in the dry season due to bush fires (Amankwah *et al.*, 2012).

Selection of study districts and communities

Stratified random sampling procedure was used in selecting the districts in all the three regions that constituted the study area. Biophysical and socio-economic data from the Ministry of Food and Agriculture (MoFA) regional directorates were reviewed and districts classified into strata based on similarities in the length of the growing period. Two strata were considered for the study in Northern and Upper West regions in which one community was randomly chosen in each stratum. Whereas in the Upper East Region, one stratum was taken due to resource limitations. Two communities were however chosen in that one stratum in the Upper East Region for the study. In all six communities were chosen randomly from the five strata, in northern Ghana for this study. The study sites are presented in Table 1.

Table 1: Administrative and geographic location of the study sites

Region	District/stratum	Community	Latitude	Longitude
Northern	Savelugu	Tibali	9.666837	-0.84398
	Tolon	Tingoli	9.3758738	-1.00936
Upper East	Kassena Nankana	Bonia	10.87064	-1.12764
	Kassena Nankana	Gia	10.869269	-1.122731
Upper West	Wa West	Guo	10.062071	-2.608257
	Nadowli	Natorduori	10.257167	-2.626606

Experimental design and management of animals

The study was conducted as a randomized complete block design with the region as a block. Each block contained two similar experimental plots (communities) and in each plot, two experimental treatments were applied and replicated three times. One block, therefore, contained six replicates of each experimental treatment. Each farmer's flock constituted one experimental unit. Thirty-six (36) smallholder sheep farmers were randomly selected for this study. Six farmers were selected in each community (3 for control and 3 for treatment application). In all, a total of 819 Djallonkè sheep belonging to these farmers were monitored. The data collected included dry matter intake of supplementary feed, dry matter intake at pasture, faecal voiding and growth performance of the Djallonkè sheep. The sheep farmers involved in this study had an average flock size of 18.6 ± 8.7.

This study was conducted in the early dry season (November to January 2013), late dry season (February to April 2014), early wet season (May to July 2014) and main wet season (August to October 2014). Each season lasted for 90 days and the whole period covered one year. The work began in November 2013 and ended in October 2014.

The animals in the pen of these farmers were randomly assigned to one of 2 feeding regimes. In the first regime, sheep were grazed daily on natural pasture from 09:00 to 17:50 h and offered crop residues and/or agro-industrial by-product (75 g DM/head/d) upon return from grazing (Control), and in the second regime, sheep were treated similarly as in the first regime but were also offered concentrate supplementary feed (Table 2) plus healthcare (CH). The concentrate feed was offered at 180 g DM/d representing 1.06% of the average live weight of animals (17 kg). All supplementary feed was offered in groups of 3-5 animals in plastic or aluminum saucepans as feeding troughs with animals having good access to feed. Water was provided all the time to animals after supplementary feeding. Animals on CH were also given orthodox healthcare package.

Crop residues offered were; groundnut haulms, cowpea haulms, pigeon pea residue, Yam and cassava peels. Agro-industrial by-products feed were corn milling waste, maize bran and rice bran. The crop residues and Agro-industrial by-products were offered at 75 g DM/head/d according to type to animals on both treatments. The samples of all supplementary feedstuff were taken daily, dried, pooled per type and sub-sampled for analysis. The composition of the crop residues and agro-industrial by-products offered across seasons are shown in Table 3 and 4.

Dominant forage species grazed by animals in the pasture were identified by observing grazing animals between 09:00 to 11:00 am and 16:00 to 17:00 pm each day for 6 d in each season in a communal pasture. Samples of the forage species identified were collected and composited. These forage samples were largely dried (about 90% DM) at sampling. The wet samples were oven-dried. After the drying, all feed samples were analyzed for their chemical composition (Table 5).

Prior to the commencement of the study, all animals were vaccinated against PPR and offered prophylactic treatment against worms and ticks. Sheep on CH received scheduled prophylactic healthcare and therapeutic medications every three months. These included vaccination with PPR-VAC vaccine (0.06 ml/kg; Botswana Vaccine Institute, Botswana) against *Peste de Petit Ruminant*, prophylactic treatment with Tectin Injectable Ivermectin (0.02 ml/kg; Mobedco-Vet, Jordan). Multivitamins were also administered intramuscularly via injection (0.5 ml/kg) with Introvit multivitamin (Interchmiewerken, Holland). Animals were dewormed with Albendazole 25% (0.3 ml/kg; Kela, Belgium). Ectoparasites were also controlled with Amiraz 20% acaricide (Mobedco-Vet, Jordan) and wounds were treated with Oxytetravet aerosol wound spray (Mobedco-Vet, Jordan) and potassium permanganate (Mobedco-Vet, Jordan). Sheep in the control group were occasionally given therapeutic treatments for ill health by the farmers until the end of the study.

Two rams (≥ 12 months) were sub-sampled from each pen for digestibility study in each season and was specifically conducted in early dry (December 2013), late dry (March 2014), early wet (June 2014) and main wet (August 2014) season.

Estimation of DM and N apparent digestibility

Dry matter intake from supplementary concentrate and crop residues were determined by weighing feed offered and left–over daily. Faecal matter voided for 24 h was collected from the 2 rams per pen for 6 d via total collection faecal bags (Arnold, 1960; Cottle, 2013). Animals were weighed every 30 d and average daily gain estimated as total body weight gain divided by 30. Total DM intake (g/d) was estimated from the 24 h total faecal collection and *in vitro* dry matter digestibility (IVDMD) of the feed consumed by animals using the equation given below (Cottle, 2013).

$$\textit{TDM intake g/d} = \textit{Faecal output of grazing animals (g DM/d)} \times \frac{100}{100 - \textit{IVDMD}\ \%}$$

TDM = total dry matter; DM = dry matter; IVDMD = *in vitro* dry matter digestibility.

Dry matter intake from the pasture was determined by taking the difference of total DM intake and supplementary feed intake (DM). Nitrogen intake (g DM/head/d) was estimated from total DM intake and N concentration in laboratory analyzed samples of the consumed feed whereas N content in faeces (g DM/head /d) was determined from daily faecal DM output and N concentration in the faeces.

Chemical analysis

All feed and faecal samples collected were dried and milled to pass through 2–mm sieve. The milled samples were then analyzed for chemical composition at the International Livestock Research Institute (ILRI) Nutrition Laboratory in Addis Ababa, Ethiopia. The feed and faecal samples DM, organic matter (OM) and ash content were analyzed following AOAC (1990) method. Nitrogen content was determined by the Kjeldahl method using Kjeldahl protein/nitrogen (Model 1026, Foss Technology Corporation, Denmark) (AOAC, 1990). Crude protein was calculated by multiplying the N content by 6.25.

Fibre component [neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL)] were analyzed according to Goering and Van-Soest (1970) method. *In vitro*, DM and OM digestibility of feed samples were determined following the two-stage digestion method of forage by Tilley and Terry (1963). The digestion process began with the incubation of 200 mg of each feed sample under anaerobic conditions with rumen fluid for 48 h at 39 °C. The rumen fluid was collected from three ruminal fistulated bulls after morning feeding. The rumen fluid was pumped with a manually operated vacuum pump from the rumen into pre-warmed thermos flasks. The rumen fluid from the two cows was mixed and filtered through four layers of cheesecloth and flushed with CO_2. This was followed by a 24 h acid-pepsin digestion at 39°C, under same anaerobic conditions. The residual feed samples were then oven-dried at 105°C for 12 h and weighed. Blanks were run alongside the samples. The *in vitro* dry matter digestibility (IVDMD) was then calculated using the following equation (Tilley and Terry,1963).

In vitro dry matter digestibility (IVDMD) % = [WS – (WR - WB) ×100] / WS
Where WS = weight of dry sample, WR = Weigh of residue and WB = Weight of blank

The residues were incinerated at 550 °C for 4 h and OM content of the residue determined. This was then used in calculating *in vitro* organic matter digestibility (IVOMD) of the feed samples as follows,

In vitro organic matter digestibility (IVOMD) % = [SOM – (ROM – BOM) ×100]/SOM
Where SOM = sample organic matter, ROM = residue organic matter and BOM = organic matter content of blank.

Statistical analysis

Data collected on dry matter and N intake, faecal output and growth performance of the sheep were analyzed in a 2 × 4 factorial arrangement of treatments by ANOVA using General Statistics software (Discovery Edition 4; VSN International 2011). Data on the fixed effects of feed supplementation plus healthcare, season and feed supplementation plus healthcare × season on DM and N intake and faecal output in faeces and weight gain of sheep were analyzed with farmer's pen as the experimental unit using the model below:

$$Y_{ijk} = \mu + CH_i + S_j + CHS_{ij} + e_{ijk}$$

where Y_{ij} is the observation (DM and N intake and voiding, weight gain, ADG,); μ is the overall mean effect; CH_i is the effect of concentrate supplementation plus healthcare (CH) or Control; S_j is the effect of season (early dry, late dry, early wet or main wet); CHS_{ij} is the interaction between feed supplementation plus healthcare and season and e_{ij} is the residual error.

Data on the effects of season on nutrient composition of feedstuffs were however analyzed for the effect of the season alone by the model below:

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where; Y_{ij} is the observation (OM, CP, NDF); μ is the overall mean effect; S_i is the effect of the season (early dry, late dry early wet or main wet) and e_{ij} is the residual error.

Differences of means were declared and compared at 0.05 by Fisher's protected least significant difference.

RESULTS

Chemical composition of supplementary concentrate and commonly grazed forage species

Analyzed CP content of the formulated concentrate supplementary feed was 157 g/kg DM with *in vitro* organic digestibility of 555 g/kg DM. The values of other chemical components are presented in Table 2.

Table 2: Inclusion levels and chemical composition of formulated concentrate supplementary feed offered to sheep under smallholder production system.

Item	**Inclusion level of ingredients (g/kg DM*)**
Ingredient composition	
Maize	300
Maize bran	282
Wheat bran	150
Fish meal	40
Soybean meal	50
Whole cottonseed	150
Common salt	8
Mineral-vitamin premix	10
Dicalcium phosphate	10
Chemical composition of concentrate feed	
Dry matter	904.4
Organic matter	899.4
Crude protein	156.9
Neutral detergent fibre	420.7
Acid detergent fibre	158.1
Acid detergent lignin	32.5
IVOMD** (g/kg)	554.8

DM* = Dry matter, IVOMD** = *in vitro* organic matter digestibility

The crude protein content of leguminous crop residues offered was not significantly different (P=0.459). Groundnut haulms had the highest CP value (112 g/kg DM) and the lowest value of 100 g/kg DM was observed in pigeon pea residue (Table 3a). Acid detergent fibre content, however, differed (P<0.01) among the leguminous crop residues. The highest (P<0.05) ADF content was found in pigeon pea residue (459 g/kg DM) and lowest in cowpea haulms (346 g/kg DM). Seasonality did not affect (P>0.05) the CP content and *in vitro* organic matter digestibility of the leguminous crop residues. It, however, affected (P<0.01) the ADL content. The highest (P<0.01) (119 g/kg DM) was observed during the early wet season and lowest in the early dry season (82 g/kg DM). Other chemical parameters of the leguminous crop residues are presented in Table 3a. Crude protein and the fibre content of root and tuber crop residues offered to sheep differed (P<0.05). The CP content of yam peels was 63 g/kg DM and higher (P=0.004) than 42 g/kg DM in cassava peels whereas ADF content of yam peels was lower (P=0.03) than that of cassava peels (Table 3b).

Nutrient content of agro-industrial by-products (AIBPs) offered differed (P<0.05) in chemical composition (Table 4). Crude protein content was highest (228 g/kg DM) in pito mash (brewer's spent grain) and lowest (65 g/kg DM) in rice bran. *In vitro*, organic matter digestibility was highest in corn milling waste and lowest in rice bran. The season did not affect the chemical composition of the AIBPs used.

Identified forage species commonly grazed in the pasture after closed observation of grazing animals in communal pasture included: *Pennisetum pedicellatum, Sida acuta, Digitaria ciliaris, Andropogon gayanus, Amaranthus spinosus, Axonopus compresus* and *Eragrostis tennella.* These were not classified into regions because the species were common in all three regions.

Season significantly affected (P<0.05) the chemical composition of identified commonly grazed forage species. The CP content of these grazed forage species was highest (P<0.05) (142 g/kg DM) during the early wet season and lowest (61 g/kg DM) in the late dry season. *In vitro,* organic matter digestibility followed the same trend as the seasonal CP content (Table 5) whereas acid detergent lignin (ADL) values of commonly grazed forage species was highest (102 g/kg DM) during the late dry season and lowest (66 g/kg DM) in the early wet season.

Table 3a: Effect of season on chemical composition (g/kg DM) of leguminous crop residues offered to sheep under smallholder production system.

Crop residues (N=12)	Season (N=3)	OM	CP	NDF	ADF	ADL	IVOMD
Cowpea (*Vigna unguiculata)* haulms	Early dry	913	96	395	248	47	664
	Late dry	873	88	456	355	60	645
	Early wet	899	119	534	409	89	561
	Main wet	881	98	504	375	76	551
Groundnut (*Arachis hypogaea*) haulms	Early dry	844	98	429	406	96	528
	Late dry	866	122	519	433	87	647
	Early wet	885	105	568	496	118	539
	Main wet	856	122	522	446	94	494
Pigeon pea (*Cajanus cajan*) residues	Early dry	883	86	567	468	104	609
	Late dry	890	79	468	454	138	467
	Early wet	884	117	584	458	150	545
	Main wet	884	117	584	458	150	545
P values	Feed	0.017	0.459	0.012	0.001	0.001	0.122
	Season	0.53	0.238	0.004	0.112	0.001	0.221
	Feed × season	0.298	0.541	0.169	0.465	0.098	0.117

OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin

Table 3b: Effect of season on chemical composition (g/kg DM) of root and tuber crop residues offered to sheep under smallholder production system.

Crop residues (N=12)	Season (N=3)	OM	CP	NDF	ADF	ADL	IVOMD
Cassava (*Manihot esculenta*) peels	Late dry	933	44	420	179	72	684
	Early wet	946	38	360	129	46	601
	Main wet	927	46	385	197	91	574
	Early dry	900	40	357	156	75	572

Yam (*Dioscorea sp*) peels	Late dry	957	56	830	84	21	703
	Early wet	950	65	792	95	26	670
	Main wet	939	59	803	96	39	532
	Early dry	851	72	468	193	94	430
P values	Feed	0.870	0.004	0.001	0.028	0.014	0.577
	Season	0.003	0.919	0.015	0.200	0.011	0.024
	Feed × season	0.24	0.612	0.053	0.091	0.06	0.354

OM = organic matter, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin

Table 4: Effect of season on chemical composition (g/kg DM) of agro-industrial by-products offered to sheep under smallholder production system.

AIBPs (N=12)	**Season (N=3)**	**OM**	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**
Rice (*Oryza sativa*) bran with hulls	Early dry	805	76	631	402	130	398
	Late dry	805	56	613	400	126	357
	Early wet	773	66	642	428	138	350
	Main wet	800	64	609	423	155	357
Maize (*Zea mays*) bran	Early dry	936	121	439	102	12	603
	Late dry	953	103	498	112	12	569
	Early wet	933	116	615	151	19	507
	Main wet	931	126	466	94	19	648
Corn milling waste	Early dry	937	95	296	64	19	655
	Late dry	923	85	504	107	28	562
	Early wet	805	100	359	89	17	533
	Main wet	943	107	379	58	15	596
Brewers spent grain (Pito mash)	Early dry	911	231	614	310	87	588
	Late dry	908	225	609	341	95	592
	Early wet	866	222	619	343	102	516
	Main wet	857	235	594	326	84	524
P Values	Feed	0.001	0.001	0.001	0.001	0.001	0.001
	Season	0.170	0.708	0.222	0.326	0.995	0.402
	Feed × season	0.716	1.000	0.294	0.966	0.989	0.985

AIBPs = agro-industrial by-products, OM = organic matter, CP = crude protein, NDF=neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin

Table 5: Effect of season on chemical composition (g/kg DM) of composite samples of identified grazed forage species in communal pasture.

Item	**Season (N=36 (9 in each season))**				**P-value**
	Early dry	**Late dry**	**Early wet**	**Main wet**	
Organic matter	871	822	833	867	0.077
Crude protein	63^{a}	61^{a}	142^{b}	120^{b}	0.001
Neutral detergent fibre	684	676	614	682	0.056

Acid detergent fibre	603[b]	682[c]	474 [a]	491 [a]	0.001
Acid detergent lignin	86[b]	102[c]	66 [a]	73[ab]	0.001
Metabolizable energy (MJ/kg)	6.2	6.8	7.1	6.6	0.218
In vitro organic matter digestibility	564[b]	446[a]	634[b]	626[b]	0.006

Means with different superscript across the rows are significantly different (P<0.05)

Apparent digestibility of DM and N **among experimental sheep**

Supplementary feed intake was higher (P<0.05) among animals on CH treatment as expected (Table 6). Intake from the pasture (DM) was similar between control and CH treatment animals but total DM intake was, however, higher (P<0.05) among animals on CH treatment than control (608 versus 515 g DM /d). With the exception of the formulated concentrate, other supplementary feed intake declined significantly from early dry season (274 g DM/d) to main wet season (70 g DM /d) in both treatments as crop residues offer by farmer's decreased towards the main wet season. Dry matter intake from pasture differed (P<0.05) across seasons. The highest pasture intake (573 g DM/d) was observed during the early wet season and lowest (274 g DM /d) in the late dry season. Consequently, total feed intake was highest (P<0.05) (679 g DM/d) during the early wet season and lowest (397 g DM/d) in the main wet season (Table 7). The interaction between feed supplementation plus healthcare and season did not significantly affect (P> 0.05) DM intake (Table 7).

Concentrate supplementation plus healthcare (CH) did not affect (P>0.05) rams' daily faecal output (251 versus 264 g DM/d for CH and control, respectively). There was however, significant (P<0.05) effect of season on faecal voiding of animals. The highest (321 g DM/d) was observed during the early dry season and lowest (169 g DM/d) in the main wet season. The interaction between feed supplementation plus healthcare and season did not affect faecal voiding of rams (P>0.05) (Table 7).

Total N intake was higher (P<0.05) among animals on CH treatment than the control group (10.5 vs 8.0 g DM/d). Nitrogen concentration in the faecal matter was not significant between the two treatments but tendered to be higher (P<0.07) among animals on CH. (Table 6). Season significantly affected (P<0.05) N intake. The highest intake (14.2 g DM/d) was observed during the early wet season and lowest (7.1 g DM/d) in the late dry season. Effect of season on N retention was also significantly higher (P=0.001) in CH treatment than the control group. The interaction of concentrate feed supplementation and season did not affect total N intake but N output was affected (P<0.05). The highest value was observed in early dry season among animals on CH treatment and lowest in late dry season in the control group (Table 7).

Growth performance of sheep and mortality rate

The CH treatment positively affected the weight gain of animals (Table 6). The animals on treatment had ADG of 34 g/d and were significantly higher (P<0.05) than 19 g/d in the control group. Consequently, total weight gain of animals on CH treatment was significantly higher (P<0.05) than the value recorded among the control group (2.3 *vs*. 1.5 kg) during the entire period of the study. Change in seasons affected (P=0.009) the effect of concentrate supplementation on ADG of animals and resulted in significant differences (P<0.05) in ADG across seasons. The effect of the treatment was higher (P<0.05) in early dry and main wet season compared to other seasons

Mortality was higher (P<0.05) among animals on control (Table 6) compared to those on concentrate feed and health provision (6.9% *vs* 3.0%). Change in seasons however, did not show significant (P>0.05) effect in mortality rate, although the values were higher among control animals in the main wet and early dry season (Table 7).

Table 6: Effect of concentrate feed supplementation plus healthcare on DM and N intake, faecal output and growth performance of sheep in smallholder production system.

Item	**Treatment**		**P Values**
	CH	**Control**	
Dry matter intake and output (g DM/d)			
Supplementary intake	203.45	109.73	0.001
Intake at pasture	404.89	405.09	0.992
Total intake	608.33	514.82	0.001
Faecal dry matter	251.22	263.68	0.277
Nitrogen intake and output (g DM/d)			
Supplementary intake	5.20	1.38	0.001
Intake of nitrogen at pasture	5.31	6.71	0.013
Total nitrogen intake	10.50	8.09	0.001
Nitrogen retention	5.16	4.02	0.027
Faecal nitrogen content	6.92	5.03	0.669
Weight gain of sheep (kg) and mortality			
Initial weight	15.79	15.53	0.608
Final weight	18.07	17.07	0.076
Total weight gain	2.29	1.54	0.024
Average daily gain (g/d)	33.64	18.86	0.001
Mortality (%)	2.97	6.86	0.004

CH = concentrate supplementation plus healthcare

Table 7: Effect of concentrate supplementation, healthcare and season on DM and N intake and faecal output in sheep kept under smallholder production system.

Item	**Early Dry**		**Late dry**		**Early wet**		**Main wet**		**P values**		
	CH	**Ctrl**	**CH**	**Ctrl**	**CH**	**Ctrl**	**CH**	**Ctrl**	**Trt**	**Season**	**Trt × season**
Dry matter *intake and output* (g DM/d)											
Supplementary	282.8^{e}	264.8^{de}	216.8^{ed}	137.0^{b}	179.2^{bc}	33.4^{a}	135.7^{b}	03.7^{a}	0.001	0.001	0.010
Mortality (%)	2.78	7.76	3.54	6.58	4.06	6.32	1.57	6.87	0.819	0.944	0.819
Intake at pasture	451.1	441.1	301.1	247.0	554.6	590.9	312.8	341.4	0.992	0.001	0.400

Total DM intake	667.8	578.0	583.3	512.0	733.8	624.3	448.5	345.2	0.001	0.001	0.943
Faecal DM	321.1	320.8	262.7	284.6	257.3	274.4	163.7	174.8	0.277	0.001	0.912
Apparent nitrogen balance (g DM/d)											
Supplementary	5.4 ^{d}	1.8^{ab}	4.8 ^{d}	3.2^{c}	5.4^{d}	0.4^{a}	5.3 ^{d}	0.1^{a}	0.001	0.019	0.001
Intake at pasture	4.6^{ab}	4.7^{ab}	3.5^{a}	2.7^{a}	9.6^{c}	13.0^{d}	3.6^{a}	6.6^{b}	0.013	0.001	0.016
Total N intake	10.0	6.5	8.2	5.9	15.0	13.4	8.8	6.6	0.001	0.001	0.763
Retention of N	4.0	3.8	2.6	2.5	9.2	6.8	5.0	2.8	0.027	0.001	0.184
Faecal N content	6.8^{c}	5.3^{b}	3.8^{a}	4.1^{a}	6.5^{c}	5.8^{bc}	3.8^{a}	3.8^{a}	0.669	0.001	0.023

Means with different superscript along the rows are significantly different (P<0.05), CH = concentrate supplementation plus healthcare. N = Nitrogen, Trt = treatment, Ctrl = control

DISCUSSION

Supplementary feeding of sheep with crop residues is commonly practiced by farmers in the study area (Karbo and Agyare, 2002). This emanates from farmer's awareness of the significant role of feed supplementation in animal productivity. Some of the supplementary feeds offered by farmers were bought as observed by Amole and Ayantunde (2016). This practice reduces the over-reliance on natural pasture that is fast depleting Osei (2012). Feed purchase also suggests that farmers are beginning to increase their investment in the production systems as rangeland diminishes due to increasing population (Thornton, 2010). The prominence of groundnut haulms and maize bran as supplementary feedstuff is due to their availability in the study area as the commonly grown crops in the farming system (Kombiok *et al.,* 2005; MoFA, 2011).

The similarity of CP content of leguminous crop residues is attributable to the fact that all belong to the same family. The residue of crops from different families often show significant differences in chemical composition (Romney *et al*., 1993; Onwuka *et al.,* 1997). The observed stability of crop residues CP content with the change in seasons confirms the report of Antwi *et al.* (2010) and is attributable to the preservation method of the collected residues. Shade dried preserved cowpea haulm protected from sun and rain was observed to have stable crude protein content throughout the dry season of about 5 months compared to decreasing CP content of standing cowpea hay (Antwi *et al*., 2010).

The observed variation in CP content of commonly grazed forage species at natural pasture in this study, which was higher during the wet season (131 g/kg DM) than in the dry season (62 g/kg DM) is due to changes in forage species composition and structural changes associated with maturity as the seasons change Powell *et al*. (1995). The values obtained were similar to the previous reports of other workers (Smith, 2002; Karbo and Agyare, 2002). The current values are however, lower than the reported values (187 g/kg DM) of CP content of natural pasture in the wet season (FAO, 2006). The differences might be due to variation in sampling methods and location of study.

The increase in total DM intake due to the offer of concentrate supplementary feed was expected. This present DM intake of 608 g DM/d among supplemented sheep was higher than 463 g DM/d reported by Salim *et al*. (2002). A similar trend of high DM intake among concentrate supplemented sheep than control group have been observed by others (Salim *et al,*. 2002; Farid *et al*., 2010). The similarity of DM intake from natural pasture observed in both treatments in this study suggest that the amount of concentrate feed offered did not cause any substitution effect on forage intake at pasture during grazing. Migwi *et al*. (2006) reported declining forage intake resulting from increasing substitution rate of poor forage with an increasing offer of concentrate feed containing high CP and energy levels. All though the quantity and quality of fodder declines in the dry seasons (FAO, 2005; Annor *et al*., 2007), animals are able to glean from the dry fodder left.

The higher significant effect of season on DM intake was largely due to feed availability differences in the pasture. Smith (2002) observed higher feed intake in sheep during the wet season compared to the dry season and attributed it to high herbage availability in the pasture as the major factor. The highest DM intake in the early wet season in this report is attributable to the presence of high quality sprouting forage species and unrestricted grazing movement of sheep (FAO, 2014; Awuma, 2012) during that season. The decline in feed availability and quality in the natural pasture from wet season to dry season has been reported to result into lower DM intake in the late dry season (Smith, 2002; Powell *et al*., 1995).

The similarity of faecal voiding (DM outflow) in both supplemented and control groups of animals (251 vs. 264 g DM/head/d, respectively) suggest higher DM retention among animals on CH treatment. Daily faecal output recorded in this work were comparable to the report of FAO (2005) and ITC (2014) who obtained faecal output of 219 to 272 g DM/head /d in sheep under free-range management system which is similar to the management system of this study. The current faecal output values are however lower than the mean value of 345 g DM/head/d observed by Powell *et al*. (1995). The differences could be attributed to environmental and breed differences of sheep.

Seasonal variation in faecal output in control group of animals (Table 7), where the highest value of 320 g DM/head/d was observed during early dry season and followed by early wet season value of 274 g DM/head/d compared to other seasons was due to low degradability of the available forage in the pasture during early dry season resulting from maturation and senescence of forage species (Campbell *et al*., 2003) whereas in the early wet season, the sprouting fresh green forage is highly degradability (Smith 2002). Although the intake was high during the early wet season. This high intake in the early wet season is associated with a high passage rate due to high digestibility of the young green forage in that season and creates more room in the rumen for intake (Smith 2002).

Higher N intake among animals on CH treatment could be attributed to the concentrate supplementary feed offered. A similar observation was made by Tadele (2014) who reported higher N intake in sheep fed grass hay and supplemented with soaked or roasted lupin grains. Luck of significant differences observed in faecal N content in both treatments (CH and control) despite the higher N intake by animals on CH treatment suggests higher N retention among animals on CH. This is in consonance with the reports that concentrate supplementation of ruminants on poor roughage diet increases feed degradation and nutrient retention due to increase in rumen microbial population and activity (Joomjantha and Wanapat, 2008; Singh *et al.,* 2011).

The observed higher N intake in early wet season resonates with the report of Salim *et al*. (2002) that N intake of grazing sheep increases during early rainy season due to high protein content of freshly grown green forage. The variation in forage quality across seasons with higher N and the lower fibre content of grazed forage in the communal pasture during the early wet season (FAO, 2006) led to the higher N intake in this season. Schlecht *et al*. (1995) reported a similar increase in N intake from 1.3% in the late dry season to 4.2% in early wet season at rangeland among ruminants in the Sahel region of West Africa. This is attributable to forage growth and senescence influenced by the rainfall pattern as asserted by other researchers (Smith, 2002; FAO, 2014; Tadele, 2014).

The highest N retention in the early wet season is attributable to the highest CP content and highly degradable available pasture in that season than other seasons (Smith, 2002). High N intake from pasture is also linked to selective grazing of animals on high-quality young sprouting forage species during early wet season (Powell *et al.,* 1996) as animals were not disturbed during that season compared to main wet and early dry season when crops are on the fields (Annor *et al*., 2007; Awuma, 2012).

The highest N intake during early wet season resulted in higher faecal N content among animals on concentrate supplementation than the control group as compared to other seasons. The value obtained in the early dry season was similar to 6.1 g DM/head/d of faecal N voided by sheep fed assorted forage species reported by (Powell *et al*., 1995). The high faecal N concentration in early wet and early dry seasons suggests that good quality manure was produced during that period and if collected through improved housing and stored in a covered pit or heap to prevent nutrient loss, it could be used for soil fertility improvement to increase crops yields.

The ADG of 34 and 19 g/d for CH and control treatments group of animals respectively, implies that the concentrate supplementation improved feed digestibility and metabolism in sheep. Similar findings were reported by (Konlan *et al*., 2012) when concentrate containing graded levels of shea nut cake was offered to Djallonke rams as a supplementary diet. The ADG values obtained in this work are similar to the report of International Trypanotolerance Center (ITC) (2014), ADG of sheep in Gambia but lower than 53 to 57 g/d reported by (Karbo *et al*., 1998), when pigeon pea forage cuttings were supplemented to sheep with untreated or urea-treated rice straw as the basal diet in the same area. The daily gain of 34 g in concentrate supplemented animals is also lower compared to ADG of 72 g/d reported by Ansah *et al*. (2012) when high level (400 g DM/head/d) of agro-industrial by-products formulated diet was supplemented to sheep in addition to free grazing from natural pasture. This could be due to the comparatively low level of supplementary feed offered in this work.

The low mortality rate observed among sheep on CH treatment as compared to control (3.0 vs 6.9%) resulted from the provision of concentrate supplementary feed and the orthodox health care. The improved nutrition and health status of the animals might have increased the immune system of animals on CH treatment. This made them become more resistant to diseases that would have normally led to the death of some animals (Campbel *et al.*, 2003). Baiden *et al.* (2009) reported similar observation among sheep and goats in coastal Savanna Ecological Zone of Ghana. The current mortality rate obtained in both treatment and control groups of animals (3.0 vs 6.9%) is lower than the 25 to 30% sheep mortality rate reported by Jagbesie (2006) in a survey of small ruminant mortality in the same area. This differences could be attributed to improved management system over the years and the initial briefing of the research participating farmers on livestock management. It is however close to the ewe mortality rate of 7.5% in the semi-intensively management system in the dryer areas of Sub-Saharan Africa countries among smallholder farmers (FAO, 2002).

CONCLUSION

The concentrate supplementation and healthcare provision package increased DM and N apparent digestibility among sheep. Seasonal changes significantly affect DM and N intake and digestibility. The highest N intake at pasture and digestibility occurs during the early wet season and nitrogen supplementation should be limited in that season to reduce feed cost. The highest faecal N content was observed in the early wet season and could be collected for fertilizing crop fields. Concentrate supplementation and healthcare provision package significantly increased daily weight gain of animals from 19 to 34 g/d. It also reduced mortality from 6.9% to 3.0%. It is therefore advisable to do concentrate feed supplementation together with appropriate healthcare provision for efficient nutrient utilization and increased growth performance in smallholder sheep production system.

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REFERENCES

Agyemang, K., 2012. Crop-based agriculture and livestock integration: conception principles and practice in Sub-Saharan Africa. In: Dei, H. K., Avornyo, F. K., Karbo. N. (Eds), Proceeding of regional workshop on Sustainable intensification of crop-livestock system in northern Ghana for increased farm productivity and food/nutrition security. August 27–28, 2012. Tamale, Ghana pp, 20–31.

Amankwah, K., Klerkx, L., Oosting, S.J., Sakyi-Dawson, O., Van der Zijpp, A.J., and Millar, D., 2012. Diagnosing constraints to market participation of small ruminant producers in northern Ghana: An innovation systems analysis. NJAS - Wageningen Journal of Life Sciences 60, 37–47.

Amole, T.A. and Ayantude, A.A., 2016. Improving livestock productivity: Assessment of feed resources and livestock management practices in Sudan-Savanna zones of West Africa. African Journal of Agricultural Research 11, 422–440

Annor, S.Y., Djang-Fordjour, K.T. and Gyamfi, K.A., 2007. Is growth rate more important than survival and reproduction in sheep farming in Ghana? Journal of Science and Technology 27, 23–31.

Ansah, T., Konlan, S.P., Ofori, D.K. and Awuda, H.A., 2012. Effect of agro-industrial by-product supplementation on the growth performance and haematology of Djalloke sheep. Ghanaian Journal of Animal Science 6, 96–100.

Antwi, C., Osafo, E.L.K., Fisher, D.S., Yacout, H.M., Hassan, A.A. and Adu-Dapaah, H., 2010. Storage practices and their effect on nutrient content and haulm availability of four dual-purpose cultivars of cowpea (*Vigna unguiculata* L.WalP) haulm. Ghanaian Journal of Animal Science 5, 32–40.

AOAC, 1990. Official methods of analysis. 15th edn. Association of Official Analytical Chemists, Washington, D C.

Arnold, G. W**.,** 1962. Harness for the total collection of faeces from grazing ewe and wether sheep Animal Production 2, 169–173. Awuma, K.S., 2012. Description and diagnosis of crop–livestock system in northen Ghana. In: Dei, H.K., Avornyo, F.K. and Karbo, N. (Eds.), Proceeding of regional workshop

on sustainable intensification of crop-livestock systems in Ghana for increased farm productivity and food/nutrition security. August 27–28, 2012. Tamale, Ghana pp, 074–086.

Ayantunde, A.A., Fernandez-Rivera, S. and Dan–Gomma, A. 2008. Sheep fattening with groundnut haulms and millet bran in the West African Sahel. Revue d'elevageet de medecine veterinaire des pays tropicaux. Ressources alimentaires 61, 215 – 220.

Baiden, R.Y. and Duncan, J.L. (2009). Performance of Djallonkè lambs raised under various management systems in Ghana. Livestock Research for Rural Development. 21, Article #193. Retrieved March 11, 2016, from http://www.lrrd.org/lrrd21/11/baid21193.htm

Campbell, J.R., Kenealy, M.D. and Campbell, K. L., 2003. Animal science: the biology, care and production of domestic animals. McGraw Hill, New York.

Cottle, D.J., 2013. The trials and tribulations of estimating the pasture intake of grazing animals. Animal Production Science 53, 1209–1220.

Diogo, R.V.C., Buerkert, A. and Schlecht, E., 2010. Resource use efficiency in urban and peri-urban sheep, goat and cattle enterprises. Animal 4, 1725–1738.

FAO, 2005. Fertilizer use by crops in Ghana pp. 21–23. Available from URL: ftp://ftp.fao.org/agl/agll/docs/fertuseghana.pdf

FAO, 2006. Food and Agriculture Organization country pasture / forage resource profile pp, 16–25.

FAO, 2002. Cattle and small ruminant production system in Sub-Saharan Africa. A system review. 47–54.

Farid, M.F.A., Shawket, S.M. and Hassan, N.I., 2010. Diet selection, feed intake capacity and performance of growing female camels: Effects of type of roughage and level of concentrates offered. Journal of American Science 6, 317–326.

Genstat, 2011. General statistics. Discovery edition (version 4) VSN International Ltd., Rothamsted Experimental Station.

Goering, H.K., and Van Soest, P.J., 1970. Forage Fiber Analysis (apparatus, reagents, procedures and some applications). USDA Agricultural Handbook No. 379.

ITC, 2014. International trypanotolerance center 2013 annual report and outlook for 2014. Banjul, the Gambia pp, 7–10

Jagbesie, S.S., 2006. Mortality in small ruminant implications for livelihoods of their keepers in Savelugu-Nanton District. Thesis submitted to the Department of Animals Science, University of Cape coast, Cape coast, Ghana.

Joomjantha, S. and Wanapat, M., 2008. Effect of supplementation with tropical protein-rich feed resources on rumen ecology, microbial protein synthesis and digestibility in swamp buffaloes. Livestock Research for Rural Development. *# 20*. Retrieved April 19, 2016. URL: http://www.lrrd.org/lrrd20/supplement/joom2.htm

Karbo, N., Bruce, J., Amekye, A.L. and Fianu, F.K., 1998. Effective management of pigeon pea (Cajanus cajan) in a crop–livestock integrated farming system in northern Ghana. Ghana Journal of Agricultural Science 31, 161–167.

Karbo, N. and Agyare, W.A., 2002. Crop–livestock system in northern Ghana. In: Tarawali G, Hiernaux, P. (eds), Improving crop–livestock systems in the dry savannas of West and Central Africa. Reports from the workshop on crop–livestock systems in the dry Savannas of West and Central Africa, 22–27 November 1998, IITA, Ibadan, Nigeria pp, 112 –126.

Kombiok, J.M., Safo, E.Y. and Quansah, C., 2005. Yield and nitrogen fixation of cowpea as affected by tillage and cropping system in the northern Savanna zone of Ghana. West African Journal of Applied Ecology 7, 95–108.

Konlan, S.P., Karikari, P.K. and Ansah, T., 2012. Productive and blood indices of dwarf rams fed a mixture of rice straw and groundnut haulms alone or supplemented with concentrates containing different levels of shea nut cake. Pakistan Journal of Nutrition 11, 566–571.

Konlan, S.P., Ayantunde, A., Addah, W. and Dei, H.H K., 2017. The combined effects of the provision of feed and healthcare on nutrient utilization and growth performance of sheep during the early or late dry season**.** Tropical Animal Health and Production. 49: 4123–1430

Migwi, P.K., I. Godwin and J.V. Nolan, 2006. The effect of nitrogen, protein and energy supplementation on voluntary intake in sheep fed low quality roughage. Proceedings of the 10th KARI biennial scientific conference, Vol 1, 12-17 November 2006, Nairobi, Kenya.

MOFA, 2011. Agriculture in Ghana. Facts and figures: Ministry of food and agriculture, statistical research and information directorate Accra, Ghana pp, 12–34.

Onwuka, C.F.I., Adetiloye, P.O. and Afolami, C.A., 1997. Use of household wastes and crop residues in small ruminant feeding in Nigeria. Small Ruminant Research 24, 233–237

Osei, S.A., 2012. Past, present and future of ruminant and non-ruminant smallholder production for intensification. In: Dei, H.K., Avornyo F.K. and Karbo N (Eds). Proceeding of regional workshop on sustainable intensification of crop-livestock systems in Ghana for increased farm productivity and food/nutrition security. August 27–28, 2012. Tamale, Ghana pp, 04–07.

Powell, J.M. and Williams, T.O., 1995. An overview of mixed farming system in Sub-Saharan Africa. In: Powell, J.M., Fernández-Rivera, S., Williams, T.O. & Renard, C. (Eds), livestock and sustainable nutrient cycling in mixed farming systems of Sub-Saharan Africa. Volume II: Technical Papers. Proceedings of ILCA International Conference, November 1993. Addis Ababa, Ethiopia pp, 523–568.

Powell, J.M., Fernhdez-Rivera, S., Hiernauxh, P. and Turner, M.D., 1996. Nutrient cycling in integrated rangeland/cropland systems of the Sahel. Agricultural Systems 52, 143–170.

Reed, J.D., Soller, H. and Woodward, A., 1990. Fodder trees and straw diets for sheep: Intake, growth, digestibility and the effects of phenolics on nitrogen utilization. Animal Feed Science and Technology 30, 39–50.

Romney, D.L., Jie, A.N., Clifford, D., Holmes, P., Richard, D. and Gill, M., 1993. Use of groundnut hay and cake as supplementary feed in Gambian N' Dama heifers exposed to trypanosomiasis. Proceedings of Africa feed resources Network workshop. August, 1993 Zimbabwe pp. 151–155.

Salim, H.M., Shahjalal, A.M.M., Tareque, A. and Kabr, F., 2002. Effect of concentrate supplementation on growth and reproductive performance of female sheep and goats under grazing condition. Pakistan Journal of Nutrition 1, 191–193.

Schlecht, E., Mahler, F., Sangare, M., Susenbeth, A. and Becker, K., 1995. Quantitative and qualitative estimation of nutrient intake and faecal excretion of zebu cattle grazing on natural pasture in semi- arid Mali. *In:* Powell, J. M., Fernández-Rivera, S., Williams, T. O. and Renard, C. (Eds), Livestock and sustainable nutrient cycling in mixed farming systems of Sub- Saharan Africa, Volume II: Technical Papers. Proceedings of ILCA International Conference, November 1993. Addis Ababa, Ethiopia pp. 149–168.

Singh, B.B., Musa, A., Ajeigbe, H.A. and Tarawali, S. A., 2011. Effect of feeding crop residues of different cereals and legumes on weight gain of Yankassa rams. International Journal of Livestock Production 2, 017–023.

Smith, T., 2002. Some tools to combat dry season nutritional stress in ruminants under African *conditions* (IAEA-TECDOC-1294). International Atomic Energy Agency (IAEA) http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/33/032/33032982.pdf

Somda, Z.C., Powell, J.M., Fernandez-Rivera, S. and Reed, J., 1993. Feed factors affecting nutrient excretion by ruminants and the fate of nutrients when applied to soil. In: Powell, J.M., Fernandez-Rivera, S., Williams, T.O. & Renard, C. (Eds), livestock and sustainable nutrient cycling in mixed farming systems of Sub-Saharan Africa, volume II. Technical papers, International Livestock Centre for Africa at Addis Ababa, Ethiopia pp, 227–243.

Tadele, Y., 2014. Supplementation with different forms of processed lupin (Lupinus albus) grain in hay based feeding of washera sheep: Effect on feed intake, digestibility body weight and carcass parameters. Journal of Biology, Agriculture and Healthcare 4, 213–232.

Tilley, J.M. A. and Terry, R.A., 1963. A two stage technique for the in vitro digestion of forage crops. Journal of the British Grassland Society, 18, 104–111

Thornton, P.K., 2010. Livestock production: recent trend and future prospects. Philophical transactions of the royal society B. British biological science 165, 2853–2867