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Nutritional quality, digestibility and growth performance of sheep fed fodder obtained from early-or-late-maturing groundnuts cultivars

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ABSTRACT

This study determined the digestibility and growth performance of sheep fed groundnut fodder obtained from early- or late-maturing cultivars. Early-maturing cultivars (90 days) included Chinese, Yenyawoso and Sumnut 23 whereas late-maturing cultivars (110 to 120 days) were Sumnut 22, Azivivi and Manipinta. Each variety was cultivated on 4 replicated fields. At maturity, all the cultivars were harvested. The pods were separated from the haulms (leaves and twigs) and equal portions of the haulms were composited into early- or late-maturing cultivars. Each of the composited haulms was then dried and chopped to a theoretical length of 3–4 cm before being used to formulate two diets that were fed to twenty-two West African Dwarf sheep (14.75±2.52 kg) in a 45-d feeding trial. Two ruminally-cannulated Nungua Black Head sheep were used to determine the digestion kinetics of the fodder in an in situ digestibility experiment whereas in vitro digestibility of the fodder at 48 h was also assessed. The early-maturing cultivars had higher concentrations of acid detergent fibre (ADF; P = 0.01) and acid detergent lignin (ADL; P = 0.02) but lower (P = 0.02) concentration of dry matter (92.4 vs. 93.3%) compared to the late-maturing cultivars. The concentration of silica differed between the two cultivars by 44%, as it tended (P = 0.08) to be higher in the late-maturing compared to the early- maturing cultivars (2.6 vs. 1.8%). The higher concentrations of ADF and ADL in the early-maturing cultivars reduced (P = 0.03) the extent of digestion of this fodder compared to the late-maturing cultivars (43.9 vs. 52.1% DM). Growth performance of sheep fed the groundnut fodder did not differ statistically (P ≥ 0.69). This study concludes that late-maturing cultivars produced more DM and had less recalcitrant fibre constituents (ADF and ADL) than early-maturing cultivars. Improvements in the extent of digestion of the late-maturing groundnut cultivars did not reflect in the growth performance of sheep fed the late-maturing groundnut fodder.

***Keywords**: Early-maturing, groundnut haulm, late-maturing, in situ digestibility, sheep.*

INTRODUCTION

More than 70% of groundnut (*Arachis hypogaea* L.) produced in Ghana is traced to the guinea savanna ecology (MoFA-SRID, 2014). This makes the zone the country's largest groundnut-producing region. Groundnut is produced for its grain as food. In many parts of West Africa, groundnut is an essential plant in the production of fodder in smallholder crop-livestock farming systems (Olorunju *et al*., 1996; Larbi *et al*., 1999). In Ghana, groundnut fodder is often utilized as supplementary feed for ruminants by small-scale farmers who rely mostly on natural grassland as source of basal feed (Konlan *et al*., 2018). In tropical Africa, smallholder crop-livestock farmers consider forage yield and quality, and seed yield as joint products with equal value and significance in the production of groundnuts (Olorunju *et al*., 1996; Larbi *et al*., 1999). In northern Ghana, income from the conservation and sale of groundnut fodder serves as an important source of household income (Konlan *et al*., 2018).

Agronomic characteristics of groundnut such as variety and duration to maturity can affect forage yield and quality. Conservation of groundnut fodder from early-maturing groundnut cultivars by sun-drying is challenged by spoilage loses associated with rainfall during harvesting in the early rainy season whereas grain and fodder yields of late-maturing groundnut cultivars are likely to be affected by drought during the late rainy season when moisture levels decline. Late-maturing groundnut cultivars may be preferred to the early-maturing cultivars by the small-scale crop-livestock farmers in subtropical Africa because late-maturing cultivars yield more forage and grain than early-maturing cultivars (Olorunju *et al*., 1996). However, insufficient rainfall towards the beginning of the dry season can reduce grain and fodder yield of groundnuts (Sesay and Yarmah, 1996). The concentration of crude protein (CP) and neutral detergent fiber (NDF) has been observed to also vary between improved than local cultivars (Omokanye *et al*., 2002). Such variations affect the nutrient quality and ruminal degradation characteristics of groundnut fodder which are directly related to animal production performance (Orskov, 1991). Late-maturing groundnut cultivars are preferred to early-maturing cultivars by smallholder crop-livestock farmers mainly because of the biomass yield and value of the fodder (Larbi *et al*., 1999) but there is no adequate data comparing the effect of maturing time on the nutritional quality and growth performance of livestock in Ghana. Such data will be useful to the integrated crop-livestock farming system where the dual objective of farmers is to maximize grain and fodder as food for human and livestock, respectively. This study determined the nutritional composition, digestibility and growth performance of sheep fed groundnut fodder obtained from early- or late- maturing groundnut cultivars.

MATERIALS AND METHODS

Climatic conditions of study areas

The groundnut fodder was obtained from 6 cultivars of groundnut cultivated on agronomic trial fields of the International Institute of Tropical Agriculture (IITA) in Duko and Tibali communities of the Savelugu-Nanton District, Cheyohi in Kumbungu District and Tingoli in Tolon District, all in the Guinea Savannah ecological zone of Ghana. The zone has a unimodal rainfall pattern that begins in late April and peaks in July to September. The mean annual rainfall is about 1200 mm (SARI, 2004). Temperature generally fluctuates between 19˚ C (minimum) and 42˚ C (maximum) with a mean annual temperature of 28.5˚ C (SARI, 2015). The mean annual day time relative humidity is 27–40%, sunshine is 80–87%. The area experiences dry cold harmattan winds from November to February and a period of warm dry conditions from March to Mid-April.

The dry season spans from October to April. During the harmattan, wild bushfires are rampant, destroying native pasture and crop residues left on the farm fields after harvest. Farmers keep cattle, sheep, goats and local poultry in an integrated management system with crop production. The commonest crops grown in the area include maize, groundnuts, cassava, yam and rice. Livestock production is mainly through the semi-intensive system of management.

Source of groundnut fodder

The groundnut cultivars were Chinese, ICGX SM 87057 (Yenyawoso), ICGV-IS 96894 (Sumnut 23), MS72.80 (Sumnut 22), RMP 12 (Azivivi), and Manipinta. Chinese, Yenyawoso and Sumnut 23 cultivars are classified as early-maturing variety with 90-day maturity period, whereas Sumnut 22, Azivivi and Manipinta were categorized as late-maturing cultivars with a maturity of 110−120 days. Each variety was cultivated on four different replicate fields measuring 2.4×4 m^2, 3.6×4 m^2, 4.8×4 m^2 and 6.0×4 m^2 in July. A pre-emergence herbicide (Stomp) was sprayed immediately after planting and Sun phosphate was applied post-emergence. Five weeks after planting weeds were removed manually with a hoe.

The early-maturing cultivars were harvested in September (rainy season) while the late-maturing cultivars were harvested in October (early dry season). At harvest, the pods were separated from the haulms (leaves and twigs) and equal portions of haulms from each variety were composited into early- or late-maturing cultivars. Each of the composited haulms was then sun-dried (92% DM) and chopped to a theoretical length of 3–4 cm before being used to formulate two diets that were fed to sheep.

Growth performance experiment

The growth performance experiment was conducted at the Livestock Unit of the Department of Animal Science, University for Development Studies, Nyankpala (0˚58'47.57" W and latitude 9˚23'45.53" N). The study was conducted during the dry season from (October – March). A total of 22 intact West African Dwarf (Djallonké) growing rams (14.75±2.52kg) were purchased from the Animal Research Institute of the Council for Scientific and Industrial Research, Nyankpala. Animals were given prophylactic treatment with Oxykel 20 L.A. (KELA, Belgium) and ivermectin 1% (Hovione, Portugal). The animals were randomly assigned to twenty-two wooden pens (2.44 m × 0.87 m) with concrete floors. The animals were adapted for 16 days to their cages and diets. Sheep were weighed on two consecutive days at the beginning and end of the experiment. The average of the consecutive weights at the beginning and the end of the study were used as the initial and final weights, respectively. Thereafter, the sheep were weighed every two weeks until the end of the experiment.

Feed ingredients (45% groundnut haulm, 20% cracked corn, 15% cassava peels, 15% whole cotton seed and 5% vitamins and minerals supplement) were mixed manually and delivered daily as a total mixed ration. The daily amount of feed offered was recorded and leftovers were collected daily, weighed and sampled before being discarded. Samples of feed that were collected daily were composited into bi-weekly samples, subsampled and stored (1^{o}C) for subsequent proximate analysis, and for in situ and in vitro digestibility experiments. DM of leftovers was determined weekly. Animals were offered their feed every morning (07:00 AM) and every evening (04:00 PM). The quantities of feed offered daily were adjusted to meet the appetites of animals. Freshwater was supplied *ad libitum* to each animal on a daily basis. Dry matter intake (DMI) of each pen was calculated as feed offered (DM basis) minus left-overs (DM basis). Daily nutrient intake was estimated based on the nutrient content of daily feed

intake. The DM intake, average daily gain (ADG), and feed efficiency (expressed as DM intake divided by ADG) were estimated for the whole 45-day experimental period. Feed offered was sampled biweekly and were used to determine DM.

In situ digestibility experiment

The in situ digestibility experiment was conducted at the Livestock and Poultry Research Centre of the University of Ghana. Biweekly sub-samples of each diet were also air-dried and ground through a 2 mm screen. Feed samples were then inserted by sequential addition method (Osuji *et al*., 1993) incubated into the rumens of two cannulated Nungua Black Head rams in duplicates for 6, 12, 24, 48, 72, 96 and 120 h to measure the rate and extent of dry matter degradation (DMD). Sheep were grazed on natural pastures with free access to water throughout the experiment. Approximately 2.0 g of DM of each feed sample was weighed into each nylon bag (7 × 14 cm; 40μm pore size). The bags were then tightly sealed and placed in the rumen of the cannulated animals. At the end of the incubation period, the nylon bags were withdrawn from the rumen and washed together with the zero-hour bag under a running tap until the dripping water was almost clear. The nylon bags were placed in an oven at 80 ^{0}C for 48 h. Digestibility of the sample was determined by the difference in weight loss during the incubation period.

In vitro digestibility experiment

Approximately 0.5 g of dried feed sample was weighed and placed into each labelled 50-ml centrifuge tube. To this tube, 28 ml of pre-warm (39 ^{0}C in a water bath) McDougall's solution was added. About 7 ml of ruminal fluid (4:1 ratio of buffer to ruminal fluid) was added according to the procedures previously described by Tilley and Terry (1963). The rumen content was obtained from two cannulated Nungua Black Head rams at the Livestock and Poultry Research Centre of the University of Ghana. The fluid was then strained through four layers of cheesecloth (with continues flushing with CO_2 gas). The ruminal fluid was placed on a stir plate to avoid settling of particles. The tubes were occasionally flushed with CO_2 as they were being filled with the rumen fluid. The tubes were capped and placed in a water bath (39 ^{0}C). Four blank tubes containing 35 ml of the McDougall's solution- ruminal fluid mixture (4:1) were also placed in the water bath. The incubation of triplicate tubes lasted for 48 h. The tubes were inverted at 2, 4, 20 and 28 h during the incubation period to suspend the sample. After 48 h of incubation, the tubes were removed from the water bath, centrifuged for 15 min at 2,000 × g and suctioned off the liquid by vacuum. Thereafter, 35 ml of pepsin solution was added to each tube. The tubes were again incubated for 48 h in a water bath (39 ^{0}C) and inverted at 2, 4 and 6 h after the addition of pepsin. After completion of the digestion, the contents of the tubes were filtered using a modified Buchner funnel and an ash-less filter paper.

The filter paper containing the filtrate was placed in an aluminum pan and oven-dried (60 ^{0}C) for 48 h and in vitro DMD after 48 h of incubation was calculated using the equation below:

$$\%\text{IVDMD} = 1 - \frac{[(\text{Residues+filter paper}) - \text{filter}] - \text{blank}}{\text{Sample weight}} \times 100$$

Chemical analyses

Feed samples composited into biweekly samples were subsampled for chemical analysis according to the official methods of analyses described by the Association of Official Analytical Chemists (AOAC, 1990). All analyses were done in duplicate with triplicate for in vitro digestibility trial. All nutrient constituents were expressed on DM basis.

Biweekly sub-samples of each diet were also air-dried and ground through a 2 mm screen to analyze neutral detergent fibre (NDF), acid detergent lignin, cellulose, silica and acid detergent fibre (ADF), using the Association of Official Analytical Chemists, method (AOAC, 1990). Briefly, after determining ADF (cellulose + lignin + silica), the residue was used for the determination of ADL. About 15ml of 72% Sulphuric acid was added to the crucible containing ADF and kept in a petri dish for 3 hours to dissolve cellulose. Cellulose was then estimated as ADF minus ADL and silica.

Statistical Analysis

Data on growth performance, was analyzed by ANOVA using the PROC MIXED procedure of the Statistical Analysis System.

In situ DMD of feed samples was estimated as the difference in DM content of the feeds before and after incubation in the rumens of sheep. For each sheep, the Data on feed disappearance for each were fitted to a non-linear regression equation with discrete lag (Mertens, 1977) using PROC NLIN procedure of SAS (SAS Institute Inc., Cary, NC, USA) for estimating the kinetics of *in situ* DMD using the following model (McDonald, 1981).

$$P = a + b\ (1 - e^{-c(t-L)}) \text{ for } t > L \quad \ldots\text{Eqn. 1}$$

Where *P* is the proportion (% DM) of DMD at time *t; a* is the soluble fraction (% DM); *b* is the slowly disappearing fraction (% DM); *c* is the rate at which *b* is disappearing (% DM per h); *t* is the discrete lag time (*h*) bags were incubated in the rumen and *L* is the lag time (*h*).

Effective DMD were estimated assuming a ruminal particulate outflow rate (k) of 0.05 per h using the following model (McDonald, 1981):

$$Effective\ DMD = a + [bc\ (c + k)]e^{-c(t-L)L} \quad \ldots\text{Eqn. 2}$$

Where *a* is the soluble fraction (% DM); *b* is the slowly disappearing fraction (% DM); *c* is the rate at which *b* is disappearing (% DM per h); *t* is the discrete lag time (*h*) bags were incubated in the rumen and *L* is the lag time (*h*).

Data on growth performance (ADG, weight gain) and in *vitro* DMD) were analyzed as a completely randomized design with each sheep and triplicate test tube as the experimental units, respectively, using the statistical model below:

$$Y_{ijk} = \mu + T_i + \varepsilon_{ijk} \ldots\ldots\ldots\ldots\ldots\ldots\text{Eqn. 3}$$

Where Y_{ijk} is the observation (ADG, weight gain, in vitro DMD); μ is the overall mean effect; T_i is the effect of maturity (early-or late-maturing cultivars; i = 1-2); ε_{ijk} is the residual error effect.

Parameters (a, b, c, effective DMD) of *in situ* degradation kinetics of feed samples from the non-linear regression in Eqn. 1 were analyzed for the effect of maturity (early or late) using the PROC MIXED procedure of SAS in completely randomized block design with each cannulated ram as a random variable in the following model:

$$Y_{ijk} = \mu + T_i + S_j + \varepsilon_{ijk} \ldots\ldots\ldots\ldots\text{Eqn. 4}$$

Where Y_{ij} = response variable (DMD, kinetics of degradation), μ is overall mean, T_i is the effect of maturity (early- or late- maturing variety (i = 1–2), S_j is the random effect of each ruminally canulated ram (j = 1–2) and e_{ij} = random error associated with each bag, assumed to be normally distributed.

Differences in least-square means due to the effect of maturity time (early- or late- maturing) were declared significant and discussed at $P \leq 0.05$. Tendencies toward significance were declared at a P-value greater than 0.05 but less than 0.10.

RESULTS

Chemical composition of diets

The proximate composition of diets obtained from early- or late-maturing cultivars of groundnuts is shown in Table 1. Except for the concentration of ADF (P = 0.01) and ADL (P= 0.02), the nutrient content of the early- and late- maturing fodder diet had no effect (P < 0.05) on their nutrient composition. There was a tendency towards higher silica (P = 0.08), and cellulose and ash (P = 0.06) concentrations in the late cultivars diet compared to the early cultivars diet.

TABLE 1. Chemical composition of diets obtained from early- and late-maturing groundnut cultivars.

Item (% DM)	Early	Late	SEM	*P*-Value
Dry matter	92.4	93.3	0.13	0.02
Crude protein	13.7	13.8	1.09	0.97
Neutral detergent fibre	33.2	30.3	0.87	0.08
Acid detergent fibre	28.7	26.4	0.27	0.01
Acid detergent lignin	7.6	6.7	0.13	0.02
Ash	8.9	8.2	0.16	0.06
Cellulose	19.2	17.1	0.53	0.06
Silica	1.8	2.6	0.24	0.08

Nutrient intake and growth performance of animal

Nutrient and DM intake of sheep are indicated in Table 2. Dry matter and intake of other nutrients were not affected by the maturity time of groundnut cultivars except for ADF (P = 0.001) and silica (P = 0.001). There was however a tendency (P = 0.06) for higher NDF intake for sheep fed the late- compared to early- maturing haulm-based diet.

TABLE 2**.** Nutrient intake and growth performance of West African Dwarf (Djallonké) growing rams fed early- or late- maturing groundnut fodder diets.

Parameter	Early	Late	SED	*P*-Value
Nutrient intake (DM basis)				
Dry matter intake (g/d)	675	716	43.2	0.36
Daily CP intake (g)	92.5	98.4	5.93	0.33
Daily OM intake (g)	615.0	657.0	39.5	0.31
Daily NDF intake (g)	228.5	258.7	15.32	0.06
Daily ADF intake (g)	196.2	193.4	0.78	0.001
Daily cellulose intake (g)	129.9	122.3	7.66	0.33
Daily lignin intake (g)	51.6	47.6	3.00	0.20
Daily silica intake (g)	12.35	18.67	1.04	0.001
Growth performance (kg)				
Initial weight	14.7	14.6	1.2	0.96
Final weight	19.1	18.7	1.2	0.77
Weight gain	4.0	4.1	0.7	0.69
Average daily gain	0.10	0.09	0.02	0.69
Feed Conversion Efficiency (DM intake/ADG)	7.4	7.7	0.97	0.74

TABLE 3 *In situ* DM digestion kinetics and *in vitro* DMD (48 h) of groundnut haulm-based diets obtained from early- or late- maturing groundnut cultivars

Item	Early	Late	SED	*P*-Value
In Sacco DM disappearance kinetics				
Rapidly degradable fraction (*a*; %)	0.94	0.94	0.054	0.99
Potentially degradable fraction (*b*; %)	55.7	70.6	8.84	0.24
Undegradable fraction (%)	33.2	29.7	2.11	0.24
Extent of digestion (%)	43.98	52.14	1.414	0.03
Lag time (h)	7.32	4.27	1.77	0.23
Fractional rate of degradation (*c*; per h)	0.170	0.132	0.09	0.69
In vitro DM digestibility				
In vitro DMD (% DM; 48 h)	70.2	63.1	8.07	0.43

In situ and *in vitro* digestibilities

Duration to maturity did not affect most parameters of the kinetics of degradation of groundnut haulm-based diets ($P<0.05$) except for the extent of digestion ($P = 0.03$; Table 3). Similarly, diets obtained from early- or late- maturing groundnut cultivars did not differ in their in vitro DMD at 48 h.

DISCUSSION

The late-maturing cultivars were harvested between the late rainy season (August-September) and the early dry season (October) where the level of rainfall was low. This explains the higher concentration of DM in this group of cultivars. Crop residues harvested in the late rainy season had higher DM concentration that inhibits spoilage and nutrient losses due to microbial spoilage caused by yeasts and moulds. This is because mouldy and mildew losses of leaves during the rainy season often reduces the nutritional quality of the fodder given that the leaves of groundnuts contain more crude protein than the stems (Larbi *et al*., 1999).

Conservation of groundnut haulms into fodder during the rainy season is difficult compared to groundnut harvested in the early dry season (October) because dry crop residues harvested in the dry season have higher concentration of DM that facilitates easier drying. Harvesting groundnut in the dry season is not, however, easier because of the difficulty of uprooting the nuts manually. The lower moisture content of the soil during the early dry season impedes uprooting of late-maturing groundnuts as many nuts are retained in the soil during harvesting (Kombiok *et al*., 2012). In most parts of West Africa, smallholder farmers who practice crop-livestock integration prefer late-maturing groundnut cultivars compared to early-maturing cultivars because the fodder yield of late-maturing cultivars is considered to be greater than early-maturing cultivars (Sesay and Yarmah, 1996; Larbi *et al*., 1999). The results of the current study are consistent with the findings of these previous studies in terms of the DM content of the fodder (Larbi *et al*., 1999) as DM concentration was greater in the late- compared to early- maturing cultivars.

Unlike the DM concentration, the differences in crude protein content of the early-or late-maturing groundnut fodder diets were not significant. This was puzzling because stress due to higher temperature as often observed in the dry season in Ghana, have variously been reported to reduce DM content and N fixation in groundnuts (Furlan *et al*., 2012; Akbar *et al*., 2017). Previous studies with many cultivars of groundnuts have

established a positive linear relationship between fodder and grain yields of groundnuts in West Africa (Larbi *et al*., 1999). This suggests that there is a dual benefit of growing groundnuts in a crop-livestock production system. Therefore, agronomic breeding efforts to increase grain yields do not appear to reduce the amount of fodder that can be generated for feeding livestock. There are many factors that are important in selecting and assessing groundnut fodder as feed in a smallholder crop-livestock production system, but biomass yield (quantity) and crude protein content (quality) appear to be the most relevant. These nutritional factors have significant effects on the nutrition of ruminants as they are related to gut-fill and rumen microbial function (Dulphy and Demarquilly,1994; Decruyenaere *et al*., 2009) which are ultimately related to animal growth performance.

The higher concentration of ADF and ADL in the early-maturing cultivars exposed to the higher temperatures of the late rainy season is not consistent with literature detailing the effect of temperature on forages elsewhere. There is evidence that suggests higher ambient temperature increases the concentration of indigestible cell wall fractions by converting products of photosynthesis into structural carbohydrates such as ADF and lignin (Buxton and Fales, 1994). Lignin has been shown to negatively correlate with forage digestibility (Jung *et al*., 1997). The data on the ADF and ADL contents of the diets is in agreement with the kinetics of digestion as the higher ADF and lignin concentration of the early-maturing cultivars was associated with the lower extent of degradability of the fodder. Silica concentration was appreciably 44% higher (2.6 vs. 1.8% DM; P = 0.08) in the late- than early- maturing groundnut diet. The effect of silica on the digestibility of forages has long been evaluated in the literature (Agbagla-Dohnani *et al*., 2003). Earlier studies have identified lignin and to a lesser extent, silica, as being the primary factors limiting the potential extent of digestion of forages (Mertens, 1977) but subsequent studies by Singh *et al*. (1989) have suggested that the factors that affect the extent of digestion may not be detectable by chemical constituents determined in the laboratory. Even though Van Soest and Jones (1968) reported an average decline of 3.0 units of digestibility per unit of silica, the findings were not conclusive with regards to legumes. This appears to still be true in the case of the present study as the relatively higher concentration of silica in the diet containing late-maturing cultivar did not reduce the digestibility of the late-maturing cultivar compared to the early-maturing cultivar. Data on the effects of season of growth and biological stage of maturity of forages ought to be interpreted cautiously to avoid confounding effects of the two factors on nutrient composition and digestibility.

The effect of maturing time on growth performance of sheep was not significant, possibly because most parameters of digestibility were not affected. Also, the feeding period of 45 d was probably not long enough to elicit significant responses in growth performance. Usually, forage with higher ADF are associated with decreases in animal growth but these effects are only observable when the animals are fed over a longer period without supplementation (Owen, 1994).

CONCLUSION

Maturity time affected DM, ADF and ADL concentration, and the extent of digestibility in favour of late-maturing groundnut cultivars. This study concludes that late-maturing cultivars have more DM and less recalcitrant fibre constituents (ADF and ADL) than early-maturing cultivars but these

favourable nutritional indices did not result in improved growth performance of sheep fed fodder obtained from late-maturing groundnut cultivars. Late-maturing groundnut cultivars are recommended in smallholder crop-livestock production systems.

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