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Assessing the nutritional quality of stored grain legume fodders: Correlations among farmers' perceptions, sheep preferences, leaf-stem ratios and laboratory analyses

D.B. Akakpo [a,b,d,*,1], I.J.M. de Boer [a], K.E. Giller [b], S. Adjei-Nsiah [c,g], A.J. Duncan [e,f], S.J. Oosting [a]

[a] Animal Production Systems group, Wageningen University & Research, P.O. Box 338, 6700 AH Wageningen, the Netherlands
[b] Plant Production Systems group, Wageningen University & Research, P.O. Box 430, 6700 AK Wageningen, the Netherlands
[c] International Institute of Tropical Agriculture, P.O. Box TL 06, Tamale, Ghana
[d] Department of Crop Science, University of Ghana, P. O. Box LG44, Legon, Ghana
[e] International Livestock Research Institute, P.O. Box 5689, Addis Ababa, Ethiopia
[f] Global Academy of Agriculture and Food Security, The Royal (Dick) School of Veterinary Studies and The Roslin Institute, University of Edinburgh, Easter Bush Campus, Midlothian EH25 9RG, UK
[g] Forest and Horticultural Crops Research Centre, Kade, University of Ghana, Legon, Ghana

A R T I C L E I N F O

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A B S T R A C T

Crop residues have the potential to alleviate annual feed shortages and nutrient deficiencies experienced in the dry season in the savanna zones of West Africa. Farmers in West Africa especially value the residues of grain legumes, also known as grain legume fodders (GLFs), as animal feed. In this study, therefore, we assessed the nutritional quality of GLFs as affected by storage conditions using four different methods: farmers' perception score (FPS), sheep preference score (SPS), leaf-to-stem ratio (LSR), and laboratory analysis of organic matter digestibility (OMD), crude protein content, neutral detergent fibre (NDF) and acid detergent fibre (ADF). We also determined correlations among these variables. The fodder of cowpea, groundnut and soybean were stored separately in three locations (rooftop, room and treefork) and with two packaging types (polythene sacks or tied with ropes) for 60, 90 and 120 days. FPS was determined by scoring the perceived quality of GLFs on a scale of 1–10 (1 = bad and 10 = good) based on physical characteristics by a group of farmers. SPS was assessed by a cafeteria feeding trial based on dry matter intake of GLFs by a flock of 12 sheep per village during a 14 hr period. LSR was determined based on the mass of the botanical fractions, i.e. leaf (leaf blade only) and stem (stem and petioles) of 200 g samples separated carefully by the hand. Laboratory analysis was done by near-infrared spectroscopy (NIRS). Results showed that all quality assessment methods successfully discriminated GLF quality differences among crops. Only farmers and sheep could distinguish quality differences among all storage conditions and packing types, whereas laboratory analyses methods could not. These findings could be due to the fact that farmers use LSR to evaluate feed quality, though colour, texture and smell of the fodder could also contribute. We also found significant correlations (ranging from 0.35 to 0.88) between all the quality assessment methods across all treatments. There were few within crop correlations between the fodder quality assessment methods, i.e. only FPS and LSR for groundnut and cowpea, FPS and CP for groundnut and all laboratory analyses parameters among each other for all crops. Hence, the differences among crops were the important determinants of the correlations. From this study, we conclude that farmers have experience and knowledge about nutritional quality of feed and livestock preference for feed. Development programmes and projects could benefit from using such knowledge when formulating and implementing interventions.

* Corresponding author at: Animal Production Systems group, Wageningen University & Research, P.O. Box 338, 6700 AH Wageningen, the Netherlands.
E-mail address: dbakakpo@ug.edu.gh (D.B. Akakpo).
[1] *Present Address: Department of Crop Science, University of Ghana, P.O. Box LG44, Legon Ghana.*

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1. Introduction

Crop residues are important livestock feeds, which form a major link between crop production and animal production in West Africa (FAO, 2014). They are the second largest feed resource for livestock after grazing, especially in the dry season. The residues of grain legumes, also known as grain legume fodders (GLFs) such as those of groundnut, cowpea and soybean, are considered more valuable feed resources than cereal crop residues, since they have relatively high nitrogen contents and digestibility (López et al., 2005; Schiere et al., 2004). Moreover, supplementation of cereal-straw based rations of ruminants with small quantities of GLFs may improve intake and utilisation of low quality feeds by supplying the limiting nitrogen and hence contribute to improved animal productivity (Oosting, 1993).

In northern Ghana and other West African countries, such as Nigeria, Burkina Faso, Mali and Niger, GLFs are harvested, dried and stored, and used by the farmers or sold to other livestock farmers, fatteners and traders as feed (Ayantunde et al., 2007; FAO, 2014; Samireddypalle et al., 2017). During the use and the marketing of these GLFs, their nutritional qualities are not determined. Market prices of GLFs could be indicative of nutritional quality, but these prices are rather determined by scarcity than by quality per se and by local preference (Ayantunde et al., 2014; Samireddypalle et al., 2017).

In determining forage quality, laboratory analyses, including wet chemical analyses (Van Soest and Robertson, 1985) and predictions based on Near Infrared Reflectance Spectroscopy (NIRS) (de Boever et al., 1995; Stubbs et al., 2010) are accepted as standard methods. Organic matter digestibility (OMD), crude protein content (CP) and fibre components are important parameters considered. Fibre components such as neutral detergent fibre (NDF) and acid detergent fibre (ADF) are combined to develop fodder quality indices, for example, the relative feed value (RFV). RFV is widely used by hay sellers and buyers in the United States of America who seek simple means of deciding which hay offers the best quality relative to the cost (Redfearn et al., 2004). However, such formal laboratory analyses are slow and expensive to conduct and are also not widely available in low-income countries.

Alternatively, fodder quality can be assessed by farmers based on the physical characteristics of the fodder using their knowledge and experience. Physical characteristics, such as colour, leafiness, maturity stage, softness and smell, are potential indicators of fodder quality. Leafiness is measured as the leaf-stem-ratio (LSR) of the fodder. Generally, more leaves means better quality, for example, of fodder from leguminous trees (Mekoya et al., 2008; Thorne et al., 1999) and pasture (Tamou et al., 2018). LSR has not been assessed as an indicator of nutritional quality for stored GLFs.

Another method of validating the quality of fodders is assessing its effect on animal performance and productivity (Coleman and Moore, 2003). However, it is challenging to conduct long-term animal performance tests with many feeds because of time and financial resource constraints. Animal performance is determined by the level of feed intake, the feed digestion and the utilisation of digested nutrients for metabolic processes. Therefore, a proxy for these tests is to evaluate forage quality by an animal preference test which assesses the rate of voluntary intake of a feed, when offered in a choice experiment with other feeds. This proxy test is the so-called cafeteria feeding experiment (Dikmen et al., 2009; Larbi et al., 1993) or choice feeding experiment (Meier et al., 2012). In this experimental setting, with ruminants, two or more feeds are offered separately at the same time for a period of time. During that period, the amount of feed consumed is the indicator of preference for the feeds on offer.

Some studies report the relationship between farmers' local knowledge about forage quality and conventional laboratory analyses. Such studies have been conducted for multi-purpose fodder trees (Mekoya et al., 2008; Thorne et al., 1999) and non-conventional feeds, such as agricultural by-products (Talore, 2015), but not yet for GLFs in sub-Saharan Africa. Moreover, the relationship between farmers' local knowledge and animal preferences is unknown. In the present study, therefore, we assessed the nutritional quality of stored GLFs using four different quality assessment methods. We explored relationships among farmers' perception score (FPS), sheep preference score (SPS), leaf-to-stem ratio (LSR), and laboratory analyses of the nutritional quality of GLFs as affected by storage conditions.

2. Materials and methods

2.1. Experimental design

The study was conducted in four villages (Tansia, Tetauko, Kaadi, and Kupalgoga) in Binduri district (10°56'01.6"N, 0°18'53.7"W) in the Upper East Region of Ghana during the dry season from December 2015 to April 2016. In this district, grain legumes are cultivated as intercrops or in a rotation with maize, sorghum and millet. These cereal grain crops benefit from these combinations with grain legumes. In this district, farmers experience feed shortages during the long dry season (November to April), and GLFs can contribute to mitigating such feed shortages. The present study used harvested fodder from an earlier study (Akakpo, 2020b) on the effect of rhizobium inoculation and phosphorus fertilisation on grain and fodder yield and quality of three grain legume crops: cowpea (*Vigna unguiculata* (L.) Walp), groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* (L.) Merr.). One farmer was selected in each village to host one replicate of the trial on his or her farm. Farmers could only participate if they had facilities to store GLFs, i.e. a rooftop, a storeroom and mature live trees with forks suitable for holding enough GLF. Only trees, such as neem (*Azadirachta indica* A. Juss) and shea (*Vitellaria paradoxa* C. F. Gaertn), that were located within a 20-metre radius of the homesteads, were selected.

The experiment was designed as a 3 × 3 × 2 factorial trial with 18 treatment combinations replicated four times in different villages (farms). The treatments included: three types of GLFs (cowpea, groundnut and soybean), three types of storage locations (rooftop, room and tree-fork), and: two types of packaging (3 kg of GLFs bundled and packed in polythene sacks or unpacked but tied with ropes).

At the time of harvest at each farm, fodders of each crop were collected on one big heap and thoroughly mixed and left to shade-dry under trees for six days to attain constant weight. After the six days of drying, each heap was mixed again and separated into 3 kg bundles. The heaps were managed to prevent leaf loss where fallen leaves were deliberately added to the 3 kg bundles both in the sacks and those tied. For each treatment combination, five bundles were stored.

2.2. Sampling

The fodders were sampled after 60, 90 and 120 days of storage. At each sampling time, about 40 g of fodder from each of the five bundles in each treatment was carefully sampled. The sampling was done by randomly picking smaller portions from three different spots on the bundles. These spots included one from the inner core and the other two were taken from the top and the bottom of the bundles. We created 200 g samples, and these samples were subsequently placed in paper bags, labelled and oven-dried at 70 °C for 48 h to determine the dry matter. The dried samples were ground to pass through a 1 mm screen with a laboratory hammer mill at the soil chemistry laboratory of the Savanna Agricultural Research Institute (SARI) – Nyankpala, Ghana. The ground fodder samples were stored at ambient temperature and later air-freighted to the animal nutrition laboratory of the International Livestock Research Institute (ILRI) in Addis Ababa, Ethiopia for analyses. The samples were freighted under the permission (Permit No.12113) of the Ministry of Agriculture and Natural Resources in Ethiopia.

At each sampling time, LSR of the GLFs was estimated for cowpea and groundnut fodder (but not for soybean fodder, which consisted only of stems and threshed pods after harvest). To estimate LSR, about 40 g of fodder from each of the five bundles in each treatment was carefully sampled, pooled and mixed. The pooled samples collected were hand separated into leaf (leaf blade only), and stem (stem and petioles) fractions and an LSR, based on mass was determined (Lemus et al., 2002).

At each sampling time, 1 kg of fodder from each treatment was put into 20-litre plastic feeding troughs to determine the farmers' perception score (FPS) and the sheep preferences score (SPS). To determine the FPS, a group of 40 farmers (10 per village) who feed GLFs to their livestock was purposively (they should own sheep and feed them with GLFs) selected from the villages. To reduced biased scoring results, the scoring procedure was explained to the selected farmers in their local language with the help of extension workers and other educated farmers who were sensitised on the subject. The farmers were asked individually to score each fodder of each treatment on a scale of 1–10 (1 = bad livestock feed and 10 =good livestock feed) based on their local knowledge on fodder quality indicators such as colour, texture and to some extent smell.

Furthermore, to determine the SPS, we randomly selected 12 sheep per village from the flock of the farmer participating in the experiment. If the farmer's flock was less than 12 mature animals, then sheep of a neighbour were added. The average body weight of the selected sheep was 15.0 kg (S.D.±3.1). At each sampling time, in a cafeteria feeding experiment (Dikmen et al., 2009; Farid et al., 2010), the 1 kg samples used in FPS determination were fed to the selected sheep. Before each preference scoring test, the sheep were groupely penned and deprived of feed and water (Cockram et al., 1999, Meyer et al., 1955) for 18 h overnight (20:00–15:00 h). In the afternoon of the following day, the 1 kg samples of each fodder from the 18 treatments were placed randomly in a confined and unroofed area of about 40 – 60 m^2. In this set-up, all sheep could select feed from any of the feeding troughs for 14 h (from 15:00 – 5:00 h) the following day. Water was also provided ad libitum during this period. Intake was determined by gathering and weighing the leftovers around and in the troughs and subtracted from the quantity offered. Assessment of SPS was done once in each period using the material stored for the respective duration (60, 90, 120 days).

$$Y_{ijklmn} = \mu + B_i + C_j + L_k + P_l + (CLP)_{jkl} + BC_{ijkl} + Dm + (CLPD)_{jklm} + \varepsilon_{ijklmn} \quad (2)$$

2.3. Sample analysis

Fodder samples were analysed for chemical composition and in-vitro organic matter digestibility (OMD) using conventional wet chemistry and Near-Infrared Reflectance Spectroscopy (NIRS). The NIRS involved predicting the organic matter (OM), dry matter (DM), crude protein (CP) content and neutral detergent fibre (NDF) concentration following development of prediction equations derived from a subset of samples analysed by conventional laboratory analysis ("wet chemistry"). Following NIRS scanning of all samples, reference samples were selected and analysed by conventional wet chemical analysis to develop prediction equations. Wet chemistry methods followed AOAC (1990) and the OMD was analysed according to Van Soest and Robertson (1985). Results from the conventional wet chemical analysis were used to calibrate the NIRS equations to predict the nutritional composition for a wide range of legume forages, such as groundnut, cowpea and soybean. NIRS predictions were made using a FOSS Forage Analyzer 5000 with software package WinISI, according to de Boever et al. (1995) and included predictions of nitrogen (N) (crude protein = N × 6.25), neutral detergent fibre (NDF), acid detergent fibre (ADF) and in-vitro organic matter digestibility (OMD). NIRS calibrations and prediction equation statistics were reported by Akakpo et al. (2020).

Results of laboratory and NIRS analyses of NDF and ADF were used to calculate relative feed value (RFV) of the GLFs. The RFV is widely used by hay buyers and sellers in the United States of America (Redfearn et al., 2004). Fodder with higher RFV indicates better nutritional quality and vice versa. The RFV was calculated using the formula by Redfearn et al. (2004) in Eq. 1:

$$RFV = 93 \times (88{\cdot}9 - 0.779 \times NDF) / ADF\ (\%\ DM) \quad (1)$$

where ADF is acid detergent fibre, and NDF is neutral detergent fibre concentration as a percentage of dry matter (DM).

This RFV was formulated relative to a typical forage quality of alfalfa hay at full bloom. If a full bloom alfalfa hay contains about 41% NDF and 53% ADF, the calculated RFV is 100 (Redfearn et al., 2004). The marketing grades of hays using RFV are: prime (>151), 1 (125–151), 2 (101–124), 3 (86–100), 4 (77–85), and fair (<77).

2.4. Statistical analyses

The data from FPS, SPS, LSR and laboratory analyses of nutritional quality were statistically analysed using a mixed-effect analysis of variance model (Searle et al., 1992) in GenStat version 19 (VSN, 2017). In this model (Eq. 2 below), replications (block), crop, storage location, packaging types and duration were fixed factors, while blocks nested with crops within village were random factors.

where, Y_{ijklmn} is the response variable (FPS, SPS, LSR and laboratory analyses of nutritional quality of the GLFs), μ is the overall mean, B_i is the effect of i^{th} block (villages), C_j is the effect of j^{th} crop (j = cowpea, groundnut and soybean), L_k is the effect of k^{th} storage location (k = rooftop room, tree fork), P_l is the effect of l^{th} packaging type (l = sack, tied), $(CLP)_{jkl}$ is the interaction effect of the main factors (crop, storage location and packaging type), D_m is the effect of m^{th} storage duration (m = at the start of the experiment (day 60, 90, 120), $(CLPD)_{jklm}$ is the interaction effect of the main factors with duration, BC_{ijkl} and ε_{ijklmn} are the random effect for crops within villages and residual error, respectively and were assumed to be normally and independently distributed around zero with variance σ^2_{crop} and $\sigma^2\varepsilon$, respectively. Tukey's HSD mean comparison procedure was used to test differences between means. Pearson correlation analyses were carried out across all observations between nutritional quality assessment methods (FPS, SPS, LSR and laboratory analyses) of the GLFs. Correlations referred are significant (P < 0.05), unless stated otherwise.

3. Results

3.1. Differences in farmers perceptions, sheep preferences, leaf-stem-ratios and nutritional composition among stored GLFs

Mean FPS differed among crops. Farmers preferred cowpea the most (6.3) followed by groundnut (5.5), and soybean the least (2.3) (Table 1). The type of storage location affected FPS. Room storage resulted in the highest FPS, followed by rooftop, while tree-fork resulted in the lowest FPS (Table 1). FPS differed for packaging type, namely GLFs packed in sacks resulted in a higher FPS than those tied. FPS of GLFs decreased with increasing duration of storage, and there was significant interaction effect between duration and crop (Table 1). There were also significant

Table 1
Farmers' perception score (FPS), sheep preference score (SPS), Leaf to stem ratio (LSR) and nutritional composition of grain legume fodders stored at different storage locations and in different types of packaging.

Treatments	FPS (n = 216)	SPS (g DMI 14 hr^{-1} 12 $sheep^{-1}$) (n = 216)	LSR[a] (n = 144)	Nutritional composition (g kg^{-1} DM) (n = 216)		RFV (n = 216)
				CP	OMD	
Crop (C)						
Cowpea	6.3	787	0.26	116	686	96
Groundnut	5.5	705	0.29	140	659	103
Soybean	2.3	472	–	97	571	68
P-value	< 0.001	< 0.001	0.054	< 0.001	< 0.001	< 0.001
LSD	0.16	70.3	0.027	8.3	19.7	7.3
Location (L)						
Rooftop	4.7	648	0.28	117	639	87
Room	4.9	710	0.30	121	643	92
Tree-fork	4.6	605	0.26	115	635	88
P-value	< 0.001	0.015	0.08	ns	ns	ns
LSD	0.16	70.3	0.033	8.3	19.7	7.3
Packaging (P)						
Sack	4.9	696	0.31	121	645	95
Tied	4.5	613	0.25	115	633	58
P-value	< 0.001	0.006	< 0.001	ns	ns	0.008
LSD	0.13	57.4	0.027	6.8	16.1	6.0
Duration (D)						
60	5.2	677	0.37	121	639	88
90	4.6	621	0.25	118	645	91
120	4.4	665	0.21	114	633	88
P-value	< 0.001	ns	< 0.001	0.004	0.05	ns
LSD	0.18	55.9	0.035	4.7	10.2	4.0
Interactions						
C × L	0.004	ns	ns	ns	ns	ns
C × P	< 0.001	ns	ns	ns	ns	ns
L × P	ns	ns	ns	ns	ns	ns
D × C	< 0.001	ns	ns	0.002	0.005	< 0.001
D × L	ns	ns	ns	ns	ns	ns
D × P	ns	ns	ns	ns	ns	ns

CP=crude protein; NDF=neutral detergent fibre; ADF=acid detergent fibre; ADL=acid detergent lignin; OMD=in-vitro organic matter digestibility; ns=not significant.
[a] LSR only applies to cowpea and groundnut fodders because soybean fodder contained no leaves

interaction effects between crop and location and crop and packaging type. These interactions effects, however, did not change the ranking order of the crops or the duration effect.

Mean SPS differed among crops. Sheep preferred cowpea, followed by groundnut and soybean the least (Table 1). The type of storage locations affected SPS. Room storage resulted in a higher SPS than rooftop and tree-fork (Table 1). Similarly, packaging affected SPS, namely GLFs packed in sacks resulted in a higher SPS than those tied. There was no duration effect on SPS.

Mean LSR tendered to be higher ($P = 0.054$) in groundnut than in cowpea. There was also a tendency ($P = 0.08$) for a location effect on LSR where room storage had a higher LSR than tree-fork (Table 1). LSR for packaging type also differed where GLFs packed in sacks had a higher LSR than those tied. LSR decreased from 0.37 to 0.21 throughout the storage period.

Mean CP and OMD of GLFs differed among crops (Table 1). There was also a duration effect on CP and OMD of GLFs with a significant interaction between duration and crop (Table 1). The interaction, however, did not affect the ranking order of the crops or the duration.

Table 2
Correlation among farmers' perception score (FPS), sheep preference score (SPS), leaf-to-stem ratio (LSR) and nutritional composition of grain legume fodders stored under different conditions and duration. For LSR only cowpea and groundnut were included in the analysis since soybean contained no leaf.

Factors	FPS	SPS	LSR	CP	OMD
SPS	0.56				
p	*< 0.001*				
LSR	0.30	0.00 ns			
p	*0.025*	*0.981*			
CP	0.49	0.35	0.24		
p	*< 0.001*	*< 0.001*	*0.004*		
OMD	0.71	0.50	0.01 ns	0.67	
p	*< 0.001*	*< 0.001*	*0.929*	*< 0.001*	
RFV	0.59	0.46	0.17	0.84	0.88
p	*< 0.001*	*< 0.001*	*0.048*	*< 0.001*	*< 0.001*

CP=crude protein; OMD=in-vitro organic matter digestibility; RFV=relative feed value.
ns = not significant

Mean RFV differed among crops. Soybean had the lowest (68) RFV belonging to the fair grade of the RFV grading standard compared to cowpea (96) in grade 3 and groundnut in grade 2 (Redfearn et al., 2004). The mean RFV for packaging type differed, where GLFs packed in sacks (95) had a higher RFV than those tied (58). There was no duration effect on RFV of GLFs, but there was a significant interaction between duration and crop. The interaction effects indicated a change in the ranking order of RFV of the GLFs with changes in duration. The ranking order of RFV on the 60th and 120th day was groundnut > cowpea > soybean while the ranking order on the 90th day was cowpea > groundnut > soybean.

3.2. Relationships among nutritional quality assessment methods

Correlations among FPS, SPS, LSR and laboratory analyses of nutritional quality of GLFs are presented in Table 2. FPS correlated significantly with SPS, LSR, RFV, CP content and OMD (Table 2), ranging from 0.30 for LSR to 0.71 for OMD. Since soybean had no leaves, the correlation between LSR and other parameters was included only for cowpea and groundnut in Table 2. Farmers distinguished among GLFs of

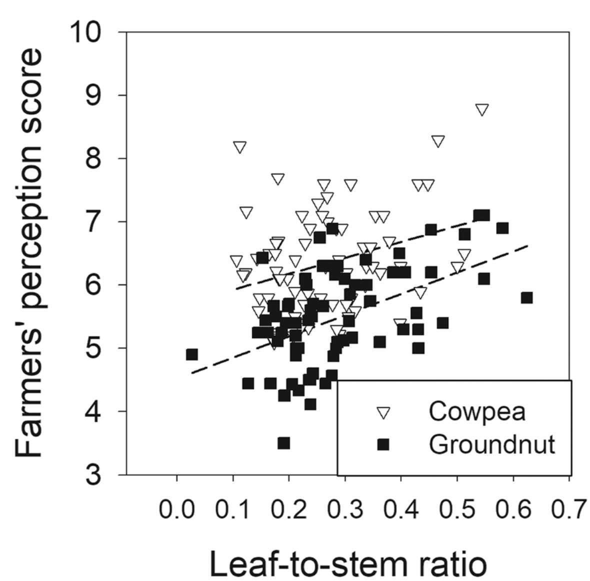

Fig. 1. Relationship between farmer's perception score (Y) and leaf-stem-ratio (X) of grain legume fodders stored under different conditions and duration. The regression relationships for individual crops were: Cowpea: y = 2.523x (SE 0.919) + 5.6749 (SE 0.26) (r^2 = 0.097; p = 0.007; n = 72; SE = 0.79) Groundnut: y = 3.3618x (SE 0.711) + 4.518 (SE 0.233) (r^2 = 0.24; p < 0.001; n = 72; SE =0.71).

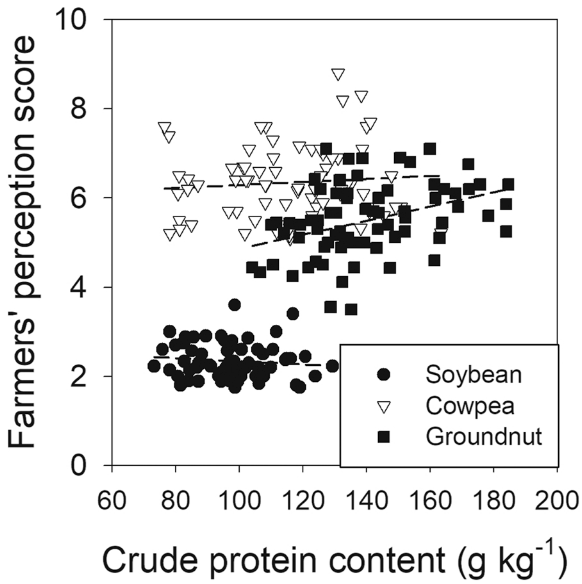

Fig. 2. Relationship between farmer's perception score (Y) and crude protein content (g kg^{-1}) (X) of grain legume fodders stored under different conditions and duration. The regression relationships for individual crops were: Cowpea: Y = 0.0034X (SE 0.005)+ 5.9495 (SE 0.561) (r^2 = 0.07; p = 0.48; n = 72; SE = 0.83) Groundnut: Y = 0.0158X (SE 0.005)+ 3.2802 (SE 0.614) (r^2 = 0.15; p < 0.001; n = 72; SE = 0.76) Soybean: Y = −0.0035X (SE 0.04) + 2.6851 (SE 0.371) (r^2 = 0.01; p = 0.36; n = 71; SE = 0.39).

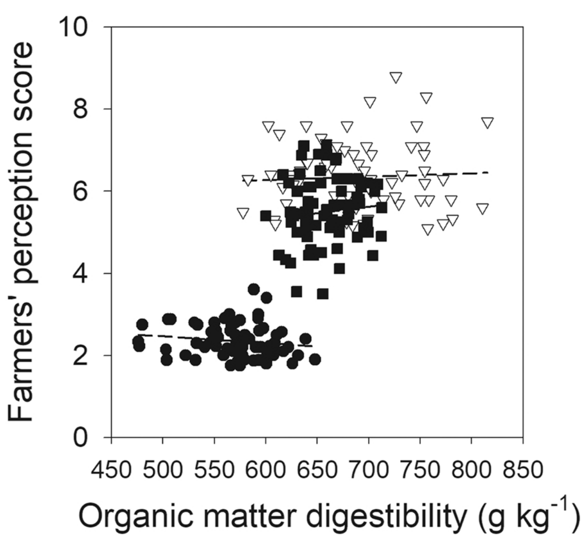

Fig. 3. Relationship between farmer's perception score (Y) and organic matter digestibility (g kg^{-1}) (X) of grain legume fodders stored under different conditions and duration. The regression relationships for individual crops were: Cowpea: Y = 0.0008X (SE 0.002) + 5.7916 (SE 1.207) (r^2 = 0.03; p = 0.65; n = 72; SE = 0.83) Groundnut: Y = 0.003X (SE 0.004) + 3.5175 (SE 2.342) (r^2 = 0.1; p = 0.4; n = 72; SE = 0.82) Soybean: Y = −0.0016X (SE 0.001) + 3.2835 (SE 0.720) (r^2 = 0.024; p = 0.2; n = 71; SE = 0.39).

different crops, and they preferred crops as feed in the order: cowpea > groundnut > soybean. Crop, therefore, was an important determinant of the correlation between FPS and quality parameters (illustrated in Figs. 1–3). Within crops, there were significant relationships among FPS and LSR for cowpea and groundnut (Fig. 1) and among FPS and CP for groundnut (Fig. 2).

SPS correlated significantly with FPS, LSR, CP content and RFV (Table 2) and ranged from 0.35 for CP content to 0.56 for FPS. Assessment of SPS was done in each period only with the crops stored for one duration, and the crops were offered to sheep that were starved for 18 h. Hence, it was expected that SPS would, at best, be able to discriminate among treatments within duration but not among durations (confirmed in Table 1). LSR was significantly correlated to all other nutritive quality parameters (Table 2), though it was only significantly correlated to FPS in cowpea and groundnut (Fig. 1). The assessed laboratory parameters CP, OMD and RFV were all significantly correlated across crops (Table 2).

4. Discussion

The present study compared different methods to assess the nutritional value of stored GLFs, namely farmers perception score (FPS), sheep preference score (SPS) based on dry (matter intake), leaf-to-stem ratio (LSR) and laboratory analyses. The results indicated that all four assessment methods were able to distinguish the nutritional quality differences among the GLFs of the three crops. It was noteworthy, however, that only farmers and sheep could distinguish the various storage locations and packaging types, whereas the most commonly used laboratory analyses parameters to predict nutritive quality, i.e. CP content and OMD, could not.

GLFs have been stored and fed to livestock for several generations in the study area. Farmers' experience would have generated a general knowledge about the nutritive quality of the GLFs and the assessment of nutritive quality differences, between and within GLFs. Such knowledge is most likely to be passed on from one generation to the other and is an element of the local knowledge of farmers (Tamou et al., 2018). Farmers in the study area use their local knowledge to assess fodder quality from its physical appearance and in some situations from its smell. These physical fodder characteristics used in the quality assessment included: colour (deep green was considered to be of better quality), stage of maturity, leafiness (more leaves means better quality) and tenderness (animals prefer softer to fibrous fodders). This local knowledge was also used by farmers to evaluate the nutritional status of soils and organic resources for soil amendment in Africa (Adjei-Nsiah, 2012; Giller, 2000). In situations where fodder is stored, the fodder should not be mouldy or rotten with a foul smell. Employing the above criteria to evaluate GLFs could be the reason why farmers were able to distinguish nutritional quality among GLFs obtained from different storage conditions, whereas laboratory assessment methods could not do. Other studies (Mekoya et al., 2008; Talore, 2015; Thorne et al., 1999) also found that forages with high ranked scores by farmers correlated positively with CP content, OMD and negatively with NDF and ADF content. In addition, farmers' local knowledge has been used in some tropical regions to determine the nutritive values of fodder trees and of grazing (Mekoya et al., 2008; Tamou et al., 2018; Thorne et al., 1999).

Our results indicate that cowpea is appreciated over groundnut, while soybean is least appreciated by both farmers and sheep (Table 1). Within crops, the LSR (leafiness) is possibly one of the criteria farmers use to judge nutritive quality as indicated by the significant correlation among FPS and LSR for cowpea and groundnut. Soybean fodder had no leaves as it is harvested dry in the field after all leaves have senesced and fallen, and farmers scored this fodder very low with limited variation among storage conditions. As described in the results section, it was not expected that sheep could differentiate among GLFs with different storage durations, and this was confirmed by the results (Table 1). The SPS could distinguish between various storage durations, in line with the fact that the overall and within duration correlation among SPS and other nutritional quality parameters were significant.

In the present study, for SPS, we offered 1 kg of GLF from each treatment to the sheep. We found that only in two cases, there was no residue of groundnut fodder after the SPS assessment. Nevertheless, the limited quantity of fodder offered could have resulted in the phenomenon that the most preferred fodder was eaten first, and forcing sheep to move to a less preferred fodder. Savadogo et al. (2000) and Zemmelink

(1980) examined the effect of the amount of feed offered and selective consumption on voluntary intake of crop residues by sheep. They found that sheep tend to eat more of the preferred fodder if the quantity offered was higher. Hence, it is likely that if we had offered more, the differences among GLFs and treatments might have been larger than now (Degen et al., 2010). Consequently, the observed differences may underestimate the real sheep preference differences. Nevertheless, GLF feeding generally is done at low levels of feed offered as a supplement to enhance the intake of low quality cereal residues such as straws of maize, rice and sorghum (Abdou et al., 2011; Ayantunde et al., 2007; Savadogo et al., 2000) in West Africa. These findings in the present study reflect the practical situation of GLF feeding in northern Ghana.

The low RFV of soybean as compared to groundnut and cowpea (Table 1) was due to higher fibre components (NDF and ADF) as reported by Akakpo et al. (2020). NDF and ADF are often used as negative indices for the nutritional quality of fodders (Van Soest, 1994) which accounted for the poor nutritive quality and ranking of the soybean fodder. These poor quality indicators could be explained by the stage of maturity at which the fodder was harvested. Plant maturity is one of the most important factors affecting forage quality. As a plant matures, fibre content and indigestible lignin accumulate. In this study, soybean fodder was the last crop harvested among the three legume crops as is often the case in the farming system of northern Ghana when almost all the leaves had fallen (Akakpo, 2020).

The fact that leaves and stems of cowpea and groundnut were quite similar in OMD and those of cowpea in CP (Akakpo et al., 2020) explains why variation in LSR did not explain variation in these laboratory analyses of nutritional quality. For groundnut, we observed a positive correlation between LSR and CP, which can be explained by the higher CP content in leaves than in stems (Akakpo, 2020a). This contradicts Larbi et al. (1999) who reported that the LSR has limited potential to predict forage quality, including CP among groundnut varieties. In other crops, such as cereals, the LSR is an important determinant of straw quality (Blümmel et al., 2010). Among and within the GLFs in the present study, OMD, CP and RFV were significantly correlated. Cowpea had a slightly higher OMD than groundnut, which may explain why it was preferred by farmers and sheep over the other GLFs.

Nevertheless, groundnut fodder tended to have higher LSR and higher CP content than cowpea fodder. LSR, at similar OMD and CP content, may have a significant correlation with intake because of the relative brittleness of leaves which facilitates particle size reduction through chewing and rumination and the passage from the rumen. This correlation was not confirmed in the present experiment.

5. Conclusion

We observed that all quality assessment methods successfully discriminated GLF quality between crops. Only farmers and sheep could distinguish quality differences among storage conditions. These findings could be due to the fact that farmers use sensory criteria (leafiness and colour (vision), smell, texture) to evaluate feed quality and that laboratory assessment methods do not assess these in this study. This finding implies that farmers have experience and knowledge about the nutritional quality of feed and livestock preference for feed. Development programmes and projects could benefit from using such knowledge when formulating and implementing interventions.

Conflict of Interest

The authors declare no conflicts of interest.

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