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Nutritional Adequacy Of Locally Available Feed Resources For Small Ruminant Production In The Guinea Savannah Agro Ecological Zone Of Ghana

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Authors

Ansah K.O
Osafo E.L.K
Antwi C
Enning S

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Corresponding Author
ojake6@yahoo.com

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Editorials
Mr. Benjamin Abugri (babugri@faraafrica.org)

Forum for Agricultural Research in Africa (FARA)
12 Anmeda Street, Roman Ridge PMB CT 173, Accra, Ghana Tel: +233 302 772823 / 302 779421 Fax: +233 302 773676 Email: Website: www.faraafrica.org : www.faradatainforms.faraafrica.org

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Designed By: Samuel Oti Attakorah - FARA Knowledge Management, Learning & Communications Unit (publications@faraafrica.org)

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FARA serves as the technical arm of the African Union Commission (AUC) on matters concerning agricultural science, technology and innovation. FARA has provided a continental forum for stakeholders in AR4D to shape the vision and agenda for the sub-sector and to mobilise themselves to respond to key continent-wide development frameworks, notably the Comprehensive Africa Agriculture Development Programme (CAADP).
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Abstract

Nutritional adequacy of small ruminant feed resources and the effect of storage on crude protein contents of predominant leguminous (groundnut and cowpea) residues were assessed in the Guinea Savannah agro-ecological zone of Ghana. Feed resources used in feeding small ruminants in two communities, Atebubu and Amantin, within the zone were sampled from six (6) farmers (three males and three females) from each community. Available feed resources ranged from household wastes like cassava peels to crop residues from maize, cowpea and groundnut and contained 72-92% DM, 76-97.2% OM, 2.8-18% Ash and 3.2-17.3% CP for Atebubu and 66.5-93% DM, 82-97.2% OM, 3.7-18% Ash and 3.7-12.5% CP. Twenty four (24) farmers were also selected for a Twenty eight (28) week trial on storage types (open and closed/Shed) effects on changes in crude protein concentration of two leguminous (Cowpea and Groundnut) residues. Storage data was analyzed with R at 5% significance. Samples of groundnut and cowpea residues in open and closed storage systems, taken at 1, 4, 8, 12, 16, 20, 24 and 28 weeks, showed no significant ($p > 0.05$) decline in CP content with storage time with CP contents reaching 11.8% at week 22 for both shed and open storage types. Crude protein content was however significantly ($p < 0.05$) lower (11.02%) in the residues under shed than in the open (12.21%) after 28 weeks. Results suggest locally available agro by-products have the potential as feed resources and can also be stored, without dramatic losses in essential nutrients like crude protein, for dry season feeding of ruminants.

Key words: Amantin , Atebubu, dry season, Leguminous, storage

Introduction

Small ruminants comprise sheep and goats and they play important roles in the food chain and livelihoods of most Sub-Saharan Africa (SSA) households (Lebbie, 2004). They are reared for religious and social purposes and as security against crop failure (Ozung et al., 2011). Small ruminants are mainly raised on crop residues, household wastes and other agro-industrial by products (AIBPs) based diets (Baiden and Obese, 2010). Crop residues and AIBPs are a vital dry season feed resource, providing livestock with feed when other resources are scarce (Valbuena et al., 2015). These resources range from peels of cassava, cocoyam, yam, plantain and banana to haulms, husks and stovers of groundnuts, cowpea and maize.
Smallholder farmers in Sub Sahara Africa are faced with feed gaps resulting from climate related drought which reduces quality and quantity as a result of feed resources (Kom et al., 2020). Boote et al. (2022) suggested storage and preservation of forages and crop residues during periods of abundance, are ways to improve dry season feed shortages and reduced animal performance. Some practical and low cost storage methods such as box-baling, room storage and bag silage of maize stover, fodder legumes, bean residues and grasses have shown considerable potential for spill-overs across feed resources and throughout SSA (Suttie, 2000).

Storage of feed has the advantage of being a feed reserve to increase productivity in seasons of drought and scarcity, ensures judicious use of excess vegetative growth and enables the storage of potentially unstable material (Cowan, 1999). Losses of nutrients, particularly crude protein, during the storage process have however been reported (Onwuka and Davies, 1996; Fasae et al., 2009; Omer, 2012). These losses may be due in part to volatilization (Merchen and Satter, 1983), exposure to sunlight, precipitation, shifts in temperature, initial autolysis (enzymatic digestion) and bacterial activity due to conditions of transporting, leaf-shattering and handling (Feyissa et al., 2014; Omer, 2012).

On-station agricultural research findings are mostly disseminated using the standard transfer of technology (TOT) model, which often leaves little room for researcher-farmer linkages (Reij and Waters-Bayer, 2001). To appreciate farmers' problems and constraints, eliminate the problem of genotype by environment interaction on variables under investigation, whip up farmers' willingness to adopt developed technologies and boost sustainability of the adopted technologies, it is very essential to conduct on-farm research (PANESA/ARNAB, 1990; Franzel et al., 2001; Gwaze et al., 2010).

The objective of this study was thus to conduct on-farm studies to assess nutrient composition of available feed resources and the effect of two storage types (open and closed/shed) and duration of storage of up to 28 weeks on the crude protein (CP) contents of groundnut and cowpea residues in the Guinea Savannah agro-ecological zone of Ghana.

Materials and Methods

Study area

The study was conducted in Atebubu (7° 45′ 1.5624″ N and 0° 59′ 6.7092″ W) and Amantin (5° 42′ 0″ N and 2° 4′ 60″ W) in the Atebubu-Amantin District (7°38′N 1°4′W / 7.633°N 1.067°W / 7.633; -1.067) in the Bono Region of Ghana. The District falls within the transitional zone between Guinea Savannah and the deciduous forest agro-ecological zone with vegetation being the interior wooded savannah type of Ghana) with a surface area of about 2,624 square kilometers. Mean monthly temperatures range from a minimum of 24°C and a maximum of 30°C with a mean annual temperatures between 26.5°C and 27.2°C (GSS, 2013). The SSW wind blows with a speed of 6kmh^{-1} and the area receives bimodal rainfall distribution with a mean annual rainfall of 1400-1800mm (GSS, 2013). The major rainy season extends from May to August whereas the minor season lasts from September to November followed by the dry season from December to April (GSS, 2013). Atebubu-Amantin is noted for the production of cowpea, groundnuts, maize, rice, sorghum and cassava in association with sheep, goats and cattle. Of the 14,283 agricultural households, 9,708 keep animals with chicken, goat and sheep making 40.7 %, 29.8% and 13.2 % respectively (GSS, 2013).

An ecological map of Ghana showing the study area is presented in Figure 1 below;

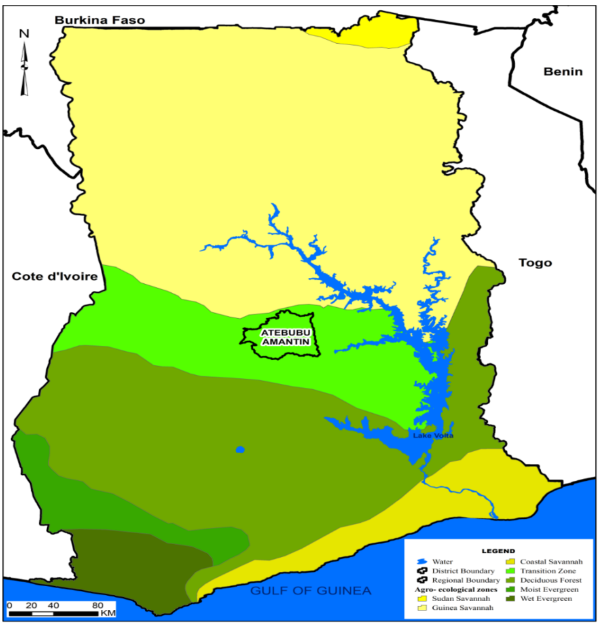


Figure 1: Ecological map of Ghana showing Atebubu-Amantin Municipality.

Selection of farmers and study design

Purposive sampling (Cresswell and Plano Clark, 2011) was used in selecting sheep and goat farming project sites based on the population of sheep and goats. Stratified sampling technique (Hamed, 2016) was employed to obtain a sample crop (cereals and legumes) -sheep or goats farm households, and other actors (farmers, butchers, traders, etc.) along the crops (cereals and legumes)-sheep and goats value chain. Each of the actors along the chain formed a stratum from which twelve (12) sheep and goat farmers (Six males and Six females) were selected. These selected farmers were those engaged in integrated crops (cereals and legumes)-sheep and goats farming for more than 3 decades with six (6) selected farmers (three males and three females) each from each of the two towns (Atebubu and Amantin) in the District. They were then designated as FARA, FARB, FARC, FARD, FARE and FARF for the study on assessment of the nutritional adequacy of available feed resources.

Storage study design

Another batch of Twenty four (24) farmers were selected for a Twenty eight (28) week trial on the effects of storage types (open and closed/Shed storage) on changes in the crude protein concentration of two leguminous residues (Cowpea and Groundnut residues). The study broadly aimed to train farmers on protein supplementation of their stock and simple ways of storing the main sources of protein supplements. After sampling of available feed resources to assess their nutrient compositions, cowpea and groundnut residues which were the main sources of protein available in adequate amounts in the study areas were stored in enclosed rooms (shed/closed storage) and in the open (open storage) to assess effect of storage type and time on changes in crude Protein (CP) concentration. The closed system of storage was done in rooms specially set aside by farmers to store the animal feed. With the open system of storage, residues were stored on raised wooden platforms in the open without any shed.

The residues under storage comprised Cowpea haulms, cowpea residues (mixture of haulms and other parts left on the field after harvest and processing), Groundnut haulms and Groundnut residues (mixture of haulms and other parts left on the field after harvest and processing). For each residue to be stored, three farmers each were selected to store each of the four groups of residues within each community under the shed and open storage systems. In all, twenty four (24) farmers comprising twelve farmers each for each storage system were selected. Storage of the residues was monitored for twenty-eight (28) weeks in a split plot design with the storage system being the main plot and the sub plot being the weeks in storage. Samples were then taken at 1, 4, 8, 12, 16, 20, 24 and 28 weeks to analyze for changes in crude protein concentration using the methods of AOAC (2002).

Chemical analysis

Samples of feed traditionally used by the farmers in both communities were collected to ascertain their organic matter (OM), dry matter (DM), ash and crude protein (CP) contents as described by AOAC (2002) at the Animal and Soil Science Laboratories of the Kwame Nkrumah University of Science and Technology (K.N.US.T.), Kumasi-Ghana. These feed resources were selected for storage and assessment of changes in crude protein concentration because of high quantities left as residues after harvesting. Groundnut and cowpea are the major legumes cultivated in the study area and so the need to educate farmers on why and how to practice protein supplementation using the high quantities of cowpea and groundnut residues available so as to have feed all year round for their small ruminants.

Five hundred grams (500g) each of residues (Cowpea and groundnut haulms and residues) each under shed/closed and open storage were scooped from various parts in the heap and mixed together in transparent zip bags at 1, 4, 8, 12, 16, 20, 24 and 28 weeks and were also analyzed at the Animal Science Laboratories of the Kwame Nkrumah University of Science and Technology (K.N.US.T.), Kumasi-Ghana for changes in crude protein concentration. Crude protein was estimated by first determining the Total Nitrogen by the Kjeldahl method and multiplying the result by a factor of 6.25 to give the crude protein (AOAC, 2002).

Statistical Design and analysis

A randomized complete block design arranged in a split plot was applied to assess the effect of changes in crude protein concentration of four leguminous residues under two storage types for a period of 28 weeks. The two storage types were the main plots and the eight sampling periods (1, 4, 8, 12, 16, 20, 24 and 28 weeks) of the residues were the sub plots weeks. Each treatment was replicated four times to get a total sample size of Sixty four (64). Sub plots were four weeks apart for a period of 28 weeks. All the storage data collected were statistically analysed using the agricolae package version 1.3-3 of R studio version 4.0.3. (De Mendiburu and Yassen, 2020). All statistical tests were done at a significance level of 5% and the Tukey HSD test was used to compare significant differences between the treatment means.

Results and Discussion

Chemical composition of feed Resources

The organic matter (OM), dry matter (DM), ash and crude protein (CP) contents of the various feed resources available in the study areas are shown in Tables 1 and 2.

Table 1. Nutrient composition of feed resources in Atebubu

ATEBUBU Farmers	Feed Resource	Content (%)			
		DM	OM	CP	Ash
FARA	Cassava peels (B)	92.0	88.0	4.3	12.0
	Maize residues (B)	91.0	88.8	3.2	11.2
	Groundnut husk (S)	82.0	90.7	8.1	9.3
FARB	Mango Leaves (B)	89.0	82.0	9.6	18.0
	Cassava peels (B)	86.0	84.0	3.5	16.0
	Maize (B)	72.0	96.0	7.9	4.0
	Cajanus cajan (S)	81.0	86.0	16.5	14.0
FARC	Maize residues (B)	87.0	92.5	3.8	7.5
	Maize (B)	88.0	97.2	8.8	2.8
	Banana leaves (B)	79.0	86.0	12.6	14.0
	Groundnut haulm (S)	89.0	91.0	12.0	9.0
	Cowpea husk (S)	89.0	88.0	7.1	12.0
FARD	Cassava peels (B)	82.0	96.0	4.4	4.0
	Pito mash (B)	90.0	94.7	4.0	5.3
	Cajanus cajan (S)	76.0	96.0	13.5	4.0
	Groundnut haulm (S)	89.0	90.0	8.3	10.0
	Cowpea husk (S)	91.2	96.0	6.8	4.0
FARE	Maize residues (B)	86.0	91.1	3.8	8.9
	Yam peels (B)	72.0	88.0	9.0	12.0
	Cooked yam (B)	84.0	93.0	6.3	7.0
	Cooked rice (B)	82.0	88.0	6.7	12.0
	Cajanus cajan (S)	81.0	91.0	15.9	9.0
	Groundnut haulm (S)	90.0	93.0	11.1	7.0
FARF	Maize (B)	92.0	97.2	8.9	2.8
	Cajanus cajan (S)	87.0	88.0	17.3	12.0
	Cowpea haulm (S)	92.0	93.0	10.4	7.0
SD		5.9	4.2	4.1	4.1

Where S= Supplement, B=Base, DM=Dry matter, OM= Organic matter, CP= Crude protein and

SD=Standard deviation. FARA, FARB, FARC, FARD, FARE and FARF= the six farmers (three males and three females) from Atebubu used in the trial.

Table 2. Nutrient composition of feed resources in Amantin

AMANTIN Farmers	Feed Resource	Content (%)			
		DM	OM	CP	Ash
FARA	Maize residues (B) Dry cassava peels (B) Groundnut haulms (S) Cowpea haulms (S)	92.0 88.2 92.0 91.0	92.5 88.0 92.0 90.1	4.8 5.8 12.5 11.0	7.5 12.0 8.0 9.9
FARB	Groundnut haulms (S) Cowpea haulms (S)	89.0 86.0	82.0 88.0	11.0 10.3	18.0 12.0
FARC	Cassava peels (B) Groundnut haulms (S) Cowpea haulms (S)	66.5 87.0 88.0	84.5 92.0 89.0	4.8 9.0 10.4	15.5 8.0 11.0
FARD	Maize residues (B) Maize (B) Cowpea haulms (S)	93.0 82.0 90.0	89.0 97.2 87.0	3.8 9.0 10.9	11.0 2.8 13.0
FARE	Cowpea haulms (S) "*Kankani*" (S)	86.0 72.0	85.0 91.0	7.8 9.0	15.0 9.0
FARF	Maize residues (B) Cowpea haulms (S) Groundnut haulms (S)	92.0 92.0 87.0	88.0 74.0 88.0	3.7 8.1 8.6	12.0 16.0 12.0
SD		7.2	5.0	2.8	3.7

Where S= Supplement, B=Base, DM=Dry matter, OM= Organic matter, CP= Crude protein and SD=Standard deviation. FARA, FARB, FARC, FARD, FARE and FARF= the six farmers (three males and three females) from Amantin used in the trial.

Feed was designated as either base or supplement depending on their type (of cereal, tuber or leguminous source) amounts required by the animal and crude protein content. Legume based residues and by-products were designated as supplements due to their high protein contents which make them required by the animals in smaller quantities compared to the cereal and leguminous sources.

The nutrient composition for basal feed resources ranged from 72-92% DM, 76-97.2% OM, 2.8-18%

Ash and 3.2-17.3% CP for Atebubu (Table 1) and 66.5-93% DM, 82-97.2% OM, 3.7-18% Ash and 3.7-12.5% CP for Amantin (Table 2). The nutrient composition of supplements also ranged from 81-92% DM, 76-96% OM, 4-14% Ash and 6.87-17.3% CP for Atebubu (Table 1) and 72-92% DM, 82-92% OM, 8-18% Ash and 8.13-12.5% CP for Amantin (Table 2).

The browse plants "Kankani" (Table 2) and Cajanus cajan (Table 1) used in the study areas had DM ranging from 72-86% because they were harvested at a relatively younger age and at high moisture content. CP contents of Cajanus cajan was within the range (i.e. above 13%) reported for West African browse species by Rittner and Reed (1992) and also agreed with the report of Getachew et al. (2000) that browse forages are higher in CP than tropical grasses and stovers. CP level of Mango (9.6) and banana leaves (12.6) indicate they could be considered in ruminant diet formulation in the tropics especially in the dry season where feed is scarce.

Pipat et al. (2011) reported low DM (26%), low protein (1.0%) and high ash (17.7%) contents for fresh cassava peels. Yam peels used as feed had higher CP and Ash contents compared to those obtained by Onwuka et al. (1997) for yam peels when they were assessing the value of various residues as feedstuffs in Nigeria. The differences might be due to the amount of flesh retained during the peeling process and the state of dryness i.e. sun-dried against the fresh peels.

Groundnut and cowpea residues comprised haulms and husks. Groundnut haulms used contained 8.3-12.5% CP, 87-92% DM, 7-12.0% Ash and 88-93% OM. Cowpea haulms available in the study areas had 86-92% DM, 74-93% OM, 7-16% Ash and 7.8-11% CP. The CP contents of cowpea husk obtained in our study were lower than those obtained by Addass et al. (2011) and Ososanyo et al. (2013).

Differences in specific nutrients (DM, OM, Ash and CP) of the feed resources available in the study areas are attributable to factors such as variety of the crop, age of residue or stage of harvest, physical composition, i.e. the leaf-to-stem ratio, length of storage, cultural and harvesting practices, processing technique/method, soil fertility and maturity. Organic matter which varied from 84-97.2% could be attributed to anatomical differences between plant species which according to Phuc (2006) depends on effect of plant development and leaf: stem ratio. The CP contents of almost all the resources designated as supplements (about 91%) were above the minimum level necessary to provide sufficient nitrogen required by rumen microorganisms to support optimum activity (McDonald et al., 2002) and the 8.9-16% level reported by Norton (1994) for optimum rumen microbial activity, maintenance and moderate growth in goats.

Effect of storage type on crude protein levels of cowpea and groundnut residues

The effect of storage type on the crude protein concentration of cowpea and groundnut residues is presented in Table 3 below;

Table 3. Storage type on crude protein (%) content of groundnut and cowpea residues

Main effects	CP (%)	SE	p Value
Storage Type			
Shed	11.02[b]	0.19	0.05
Open	12.21[a]		
Residue			
Cowpea haulm	10.88[a]	0.09	<0.001
Cowpea Residue	12.27[c]		
Groundnut haulm	11.52[b]		
Groundnut residue	11.79[b]		
Statistical Interactions			
Storage x week			<0.001 (**)
Residue x week			0.66 (NS)
Residue x Storage			0.02 (**)
Residue x Storage x Week			0.09 (NS)

** $p < 0.05$; SE = standard error; NS = Not significant; CP = crude protein.

Storage type significantly (*$p \leq 0.05$*) affected CP content of leguminous residues. Significant differences (*$p \leq 0.05$*) were observed in the crude protein contents between cowpea haulms and but between groundnut haulms and groundnut residues, no significant differences were observed in their crude protein contents after storage. Crude protein content was significantly (*$p < 0.05$*) lower (11.02 %) in the residues stored in the shed than those stored under open (12.21 %). cowpea residues but between groundnut haulms and groundnut residues, no significant differences were observed in their crude protein contents after storage. Crude protein content was significantly (*$p \leq 0.05$*) lower (11.02 %) in the residues stored in the shed than those stored under open (12.21 %). No interactions (*$p = 0.66$*) occurred between residue type and weeks in storage. Significant interactions however occurred between residue and type of storage (*$p<0.02$*) as well as the storage type and the duration of storage (*$p<0.001$*).

The crude protein content of residues remained similar (11.8 %) after week 26 for both shed and open storage types (*Figure 2*). In contrast to the increase in crude protein contents of residues in storage under the open system, there was an insignificant decline in the crude protein content of residues with time in the shed storage (*Figure 2*). With the residue and storage type with time, no significant interactions (*p=0.09*) were observed.

Figure 2 shows the effect of different storage practices on the crude protein concentration of groundnut and cowpea residues.

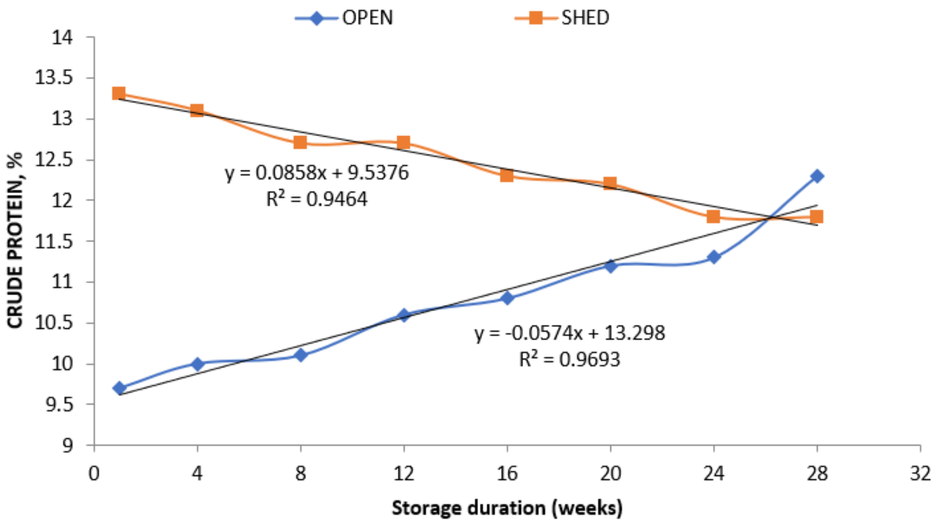
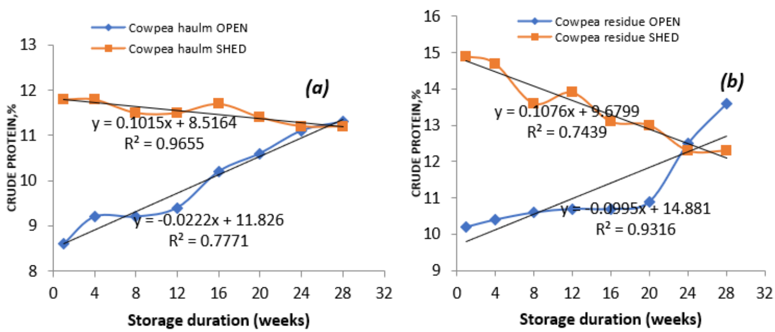


Figure 2: Effects of type of storage on crude protein concentration of groundnut and cowpea residues.

The crude protein level of the residues under the shed or closed system of storage declined gradually from 13.3% with time but stabilized at 11.8% after twenty-eight (28) weeks. Similar observations in the decline of crude protein of ensiled grass and legume hays have been reported by Onwuka and Davies (1996).

Figure 3 shows changes in crude protein contents of groundnut and cowpea residues over time



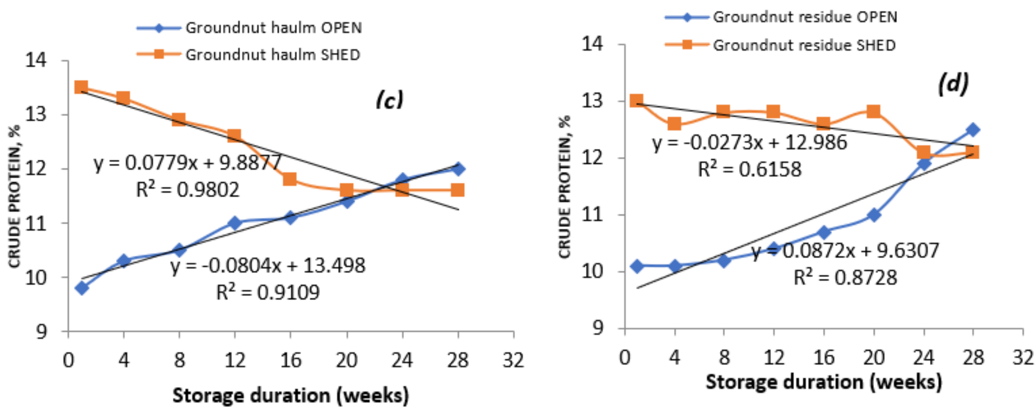


Figure 3: Changes in crude protein concentration under open and closed storage over time of (a) Cowpea haulms (b) Cowpea residues (c) Groundnut haulms and (d) Groundnut residues.

Residues stored in open had crude protein contents increasing with time with the reverse occurring for residues stored in the sheds (Figure 3) These are contrary to observations by Feyissa ***et al.*** (2014) and Guerrero ***et al***. (2010), who found that storage conditions are the main factors responsible for nutrient loss or retention during storage and that loss in nutrient quality is more and faster when residues are stored outdoor and unprotected from adverse weather conditions. After 28 weeks of storage under sheds, crude protein concentration declined from 11.8-11.2%, 14.9-12.3%, 13.0-12.1% and 13.5-11.6% for Cowpea haulms, Cowpea residues, Groundnut residues and Groundnut haulm respectively. For storage in the open, crude protein concentration increased from 8.6-11.3%, 10.2-13.6%, 10.1- 12.5% and 9.8-12.0% for Cowpea haulms, Cowpea residues, Groundnut residues and Groundnut haulm respectively.

The decline in CP contents of the residues as storage length increases agrees with the findings of Oladotun ***et al***. (2003) who observed reduction in the crude protein with increased storage length. Another trial by Antwi ***et al.*** (2011) to assess roof, shed and field storage on nutrient retention in dual-purpose cowpea haulm over time showed that crude protein remaining declined in the cowpea haulms in the field storage followed by roof with the shed storage retaining quality of haulms. The fall in crude protein content in this study may be due to volatilization (Merchem and Satter 1983).

The increase in crude protein content associated with the open system of storage could be attributed to exposure to rain and sunlight. The heat generated in the residue as a result of wetting and drying can result in Maillard reaction leading to protein-fibre complex (Oh ***et al***., 2018). This explains the gradual increase in protein concentration with time in open storage and this bound protein will eventually not be available to the animal. The increase in crude protein concentration is also consistent with the studies of Rotz ***et al***. (1991), who suggested that, in the event of rain, soluble nitrogen leaches at a slower rate than other constituents such as sugars, thereby causing nitrogen concentration to increase.

At the end of the storage, the CP content of fodder in storage (11 to 12.3) was similar to the level (11 to 12) required for moderate level of ruminant production (Gatenby, 2002), thereby suggesting its adequacy for ruminant production. This indicates that the cowpea and groundnut residues, when available in adequate amounts in the study areas (Atebubu and Amantin) during the cropping season and after harvesting of the main or edible parts for man's usage, can be stored for dry season feeding of ruminants without dramatic losses in crude protein concentration.

Conclusion

Since the residues stored using the open and closed/shed systems retained most of the crude protein over a long period, they can be adopted during the major season of crop harvest, where fodder is available in larger quantities, to store fodder for dry season feeding where fodder is limiting both in quantity and quality.

Farmers mostly left leguminous and other crop residues which serves as fodder on the field because of difficulties in transportation, hence strategies like simple box baling would be recommended to ease transporting as well increase the space required to store these residues to be used to feed ruminants during periods of feed scarcity like the dry season.

Data availability and conflict of interest

The data used to support the findings of this study can be made available upon request from the corresponding author. The authors also declare that there is no conflict of interest with regards to authorship and publication of this article.

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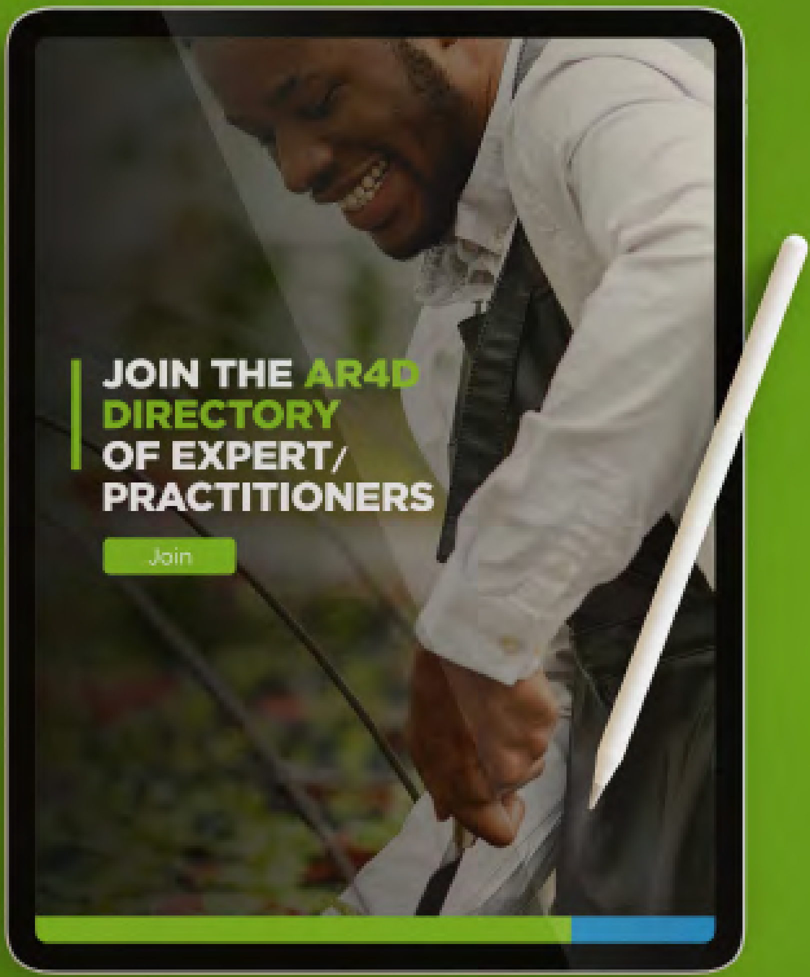

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