Chemical Composition and Nutritive Value of an Invasive Exotic Species Broussonetia Papyrifera in Ghana

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Abstract
The study was done to determine the chemical composition and nutritive value of *Broussonetia papyrifera* with the aim of determining its potential for forage in Ghana. Due to its prolific regeneration pattern it has invaded large canopy gaps and degraded farm lands with a lot of ecological consequences. Foliage samples of *Broussonetia papyrifera* were collected from wild stands in the Tano South District of the Brong Ahafo Region, Ghana, together with samples of *Ficus exasperata* and *Leucaena leucocephala* for comparison. The nutrient content (proximate composition, cell wall content and macro-mineral composition), anti-nutritive factor (condensed tannin) and digestibility of the test species were analysed. Results of the study showed that for a cheaper source of plant crude protein (27.17% DM), ether extract (6.45% DM), carbohydrate (25.37% DM), ash (11.54% DM), calcium (2.54% DM), phosphorus (0.23% DM), potassium (0.73% DM), magnesium (0.86% DM) and in vitro organic matter digestibility (50.88% DM), *B. papyrifera* appears good potential forage in ruminant nutrition. However, the level of condensed tannin (CT) in *B. papyrifera* (6.96% - 7.09% DM) may interfere with animal performance since they exceed 5.0% DM concentration which may reduce the digestibility of forage as a result of the nitrogen-condensed tannin (N-CT) complex formation that reduces their solubility and degradation by rumen bacteria. The results suggest that *B. papyrifera* could be a good candidate for forage, especially during the dry season for resource-poor farmers with stalled-fed animals in the *B. papyrifera* invaded areas in Ghana.
Keywords: Invasive species, chemical composition, nutritive value, forage, *Broussonetia papyrifera,* Ghana

1.0 Introduction

Broussonetia papyrifera (paper mulberry) is an exotic tree species of the moraceae family native of the Indo-Malayan region, China, Japan and the pacific region. It is widely grown for paper production in its native home (Delizio, 1953). *Broussonetia papyrifera* was introduced into Ghana by the Forestry Research Institute of Ghana (FORIG) in 1969 to form part of an experimental programme to identify species for the local production of industrial cellulose (Anon, 1970). However, due to its prolific regeneration pattern it got out of hand and invaded large canopy gaps and degraded farmlands in and outside the two forest reserves where the species was introduced.

Recently, however, it is being argued that means of enhancing the value of *B. papyrifera* for use must be exploited rather than eradication. There are claims by some farmers of good food crop yield on soils under *B. papyrifera* stands. Generally, farmers in the invaded areas in Ghana use the bark as one of the reliable materials for tying goods while the wood serves as a highly inflammable fuel wood (Personal observation). There are claims by some farmers of good food crop yield on soils under *B. papyrifera* stands. The leaves of the species are also used by farmers to feed livestock, especially during the dry season (Personal observation). Other uses of *B. papyrifera* identified by Owusu and Appiah (2014) include medicinal value, fibre/cloth, living fence, hedge or visual/ noise barrier, control of erosion, the fruits and leaves serve as food for animals. In a study on the potential utilization of *B. papyrifera* as timber resource in Ghana the study has shown that *B. papyrifera* wood has good characteristics which could make it a utility material for the furniture, handicraft, building and construction industries (Owusu and Appiah, 2014).

A review of literature indicates that there is limited information on the nutritive value of *B. papyrifera*. Lin *et al.* (1988) in a study in China observed high protein content (84.8%) and good efficiency of nitrogen utilization in *B. papyrifera* tree leaves when fed to Formosa Sika deer (*Cervus nippon taiouanus).* However, the results of Lin *et al.* (1988) which is animal-specific does not represent the general situation. Since variations in nutritive value of a species when planted outside its geographical range is possible, there is the need to carry out thorough studies on *B. papyrifera* in Ghana to unearth its forage potential. The taxonomy (Liao, 1989), reproduction (Jacalne, 1959), physical and mechanical properties of the wood (Goulatie *et al*., 1981) and uses (Marten, 1975) of *B. papyrifera* have been well documented. Studies done in Ghana on the species by Agyemang (2000) include the seedling growth response to light and drought, fruiting and viability patterns, seed dispersal mechanisms, preferred micro sites, competitive ability in association with some indigenous forest tree species, natural regeneration and its recovery after fire.

The study intends to provide information that could lead to incorporation of *B. papyrifera* leaves in feed sources for small ruminants especially during the dry season. This could form part of the efforts at ensuring food and income security of livestock farmers in the B. *papyrifera* areas of Ghana. This study was carried out to determine the nutritive value of *B. papyrifera* leaves and to assess the effect of seasons on the nutritive value of the species. Two species, *F. exasperata* and *L. leucocephala* were included in the study for the purpose of comparison. *Leucaena leucocephala* is a well-known leguminous species that has globally been used for ruminant feeding while *F. exasperata* is also widely used as ruminant feed in Ghana.

2.0 Methodology

2.1 Study Site and Sample Selection

The plant species for the experiment which include; *B. papyrifera*, *F. exasperata* and *L. leucocephala*, were collected from the Tano South District in the Brong Ahafo Region. The area lies between latitudes 7° 00′ and 7° 25′ north and between longitudes 1° 45′ and 2° 15′ west. It lies in the Dry Semi- Deciduous Forest Zone (DSDFZ) of Ghana with Wet semi-equatorial climatic type (Hall and Swaine, 1981). The site experiences double maximum rainfall pattern, from April to July and from September to October. The mean annual rainfall is 1304.3mm. The dry season occurs between the months of November and March. The mean monthly temperatures of the district range between 22°C (August) and 30°C (March) (Meteorological Agency, 2009). The soil of the area consists of forest ochrosols and the rubrisol-ochrosol intergrades. The samples (*B. papyrifera*, *F. exasperata* and *L. leucocephala)* were collected in two different seasons wet (January) and dry (May).

2.2 Data Collection and Analysis

Collection and sample preparation of forages

Quantities of *B. papyrifera, F. exasperata* and *L. leucocephala* leaves from mature plants were cut from the tips of branches and stored in moisture free environment *Ficus exasperata* is an indigenous non-leguminous plant that has been widely used to feed livestock. *Leucaena leucocephala* is a leguminous plant with known nutritional quality and recommended as a palatable forage species for ruminant livestock. Both *B. papyrifera* and *L. leucocephala* are classified as invasive species. Also *B. papyrifera* and *F. exasperata* belong to the same family Moraceae. Representative samples of 100g of the three plant species were oven-dried at a temperature of 65ºC to a constant weight and stored in a clean plastic container (AOAC, 1990).

Chemical analysis

Dried leaf samples of *B. papyrifera*, *F. exasperata* and *L. leucocephala* were ground in an electric grinder and passed through a 1mm-sieve. The nutrient analysis of the investigated species was carried out at the Department of Biochemistry and Biotechnology laboratory of the Faculty of Biosciences of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The dry matter, crude protein, crude fibre, ether extract, and ash were determined using procedures in the Association of Official Analytical Chemists (AOAC, 1990). Carbohydrate content was determined by difference between 100 and the sum of the dry matter, crude fibre, crude fat, crude protein and ash contents in the sample (AOAC, 1990), *in vitro* digestibility (Gerri and Sottini, 1970), acid detergent fibre, neutral detergent fibre, lignin (Georing and Van Soest, 1970) and condensed tannin (AOAC, 1990). Macro mineral determination was carried out based on standard procedures as outlined in AOAC (1990). All the parameters analysed were carried out in three replicates for each season (dry and wet seasons). The replicates were made from different samples from five different trees on the same collection site.

Data analysis

The General Linear Model Procedure of Statistical Analytical System (SAS, 1999) was used to analyse the data. The proximate and mineral compositions as well as other constituents for the forage species investigated during the dry and wet seasons were subjected to analysis of variance (ANOVA). Significantly different means were separated using the least square mean (LSM) analysis procedure.

3.0 Results

3.1 Effect of season on proximate composition of the three forage species

Leucaena leucocephala had more dry matter than that of *B. papyrifera* and *F. exasperata* ($P<0.05$). Dry matter for the dry season tended to be higher ($P<0.05$) in all the species than in the wet season. However, the wet season dry matter for *L. leucocephala* was higher than that of *F. exasperata* and *B. papyrifera*. Dry matter for *F. exasperata* in the wet season was the lowest and the concentration was equivalent to that of *B. papyrifera* ($P<0.05$). The dry matter composition in the forages ranged from 29.37% - 47.32% DM (Table 1). Results presented in Table 1 show that the crude protein concentration ranged from 18.39% – 30.06% DM. *Leucaena leucocephala* had the highest among the three forage species ($P<0.05$). Moreover, the crude protein concentration in the wet season appeared to be higher ($P<0.05$) in all the forage species than in the dry season. *F. exasperata* recorded the lowest concentration in the wet season. The dry season crude protein for *L. leucocephala* was also higher than that of *B. papyrifera* and *F. exasperata*. The crude protein for *B. papyrifera* (wet season) and *F. exasperata* (wet season) were not significantly different ($P>0.05$).

Leucaena leucocephala had the highest crude fibre concentration (14.17%-18.26% DM) among all the species for both the wet and dry seasons (P<0.05). However, the dry season concentration of crude fibre for *L. leucocephala* was higher than the wet season concentration. The wet season crude fibre for *B. papyrifera* and *F. exasperata* were higher than their dry season concentrations. The dry season crude fibre for *B. papyrifera* was the lowest (7.87% DM) among the investigated species (P<0.05). The crude fibre composition in the forages ranged from 7.87% - 18.26% DM. The concentration of neutral detergent fibre (NDF) in *B. papyrifera* was higher than that obtained in *F. exasperata* and *L. leucocephala* (P<0.05). Neutral detergent fibre for the dry season tended to be higher in all the forage species than in the wet season. However, the dry season NDF was higher in *B. papyrifera* than *F. exasperata* and *L. leucocephala* (P<0.05). In the wet season, *F. exasperata* recorded the lowest NDF among the three species. The NDF composition in the forages ranged from 25.58% - 34.76% DM (Table 1).

The acid detergent fibre (ADF) was highest in *B. papyrifera* than *F. exasperata* and *L. leucocephala* (P<0.05). The wet season ADF concentrations of the forages were higher than the dry season, except in the *F. exasperata.* In the dry season, ADF concentration was lower (P<0.05) in *L. leucocephala* than in the other forages. *F. exasperata* contained the least concentration of ADF in the wet season. The ADF composition in the forages ranged from 10.45% - 31.87% DM (Table 1). The ether extract in *B. papyrifera* was more than that obtained in *F. exasperata* and *L. leucocephala* (P<0.05). Ether extract in the wet season appeared to be higher than dry season concentrations in *B. papyrifera* and *L. leucocephala*. The dry season concentrations of ether extract in *F. exasperata* and *L. leucocephala* are similar (P<0.05). However, *F. exasperata* had the least concentration of ether extract in the wet season. The ether extract composition in the forages ranged from 3.82% - 6.45% DM (Table 1).

The concentration of carbohydrate was highest (P<0.05) in the *F. exasperata* than *B. papyrifera* and *L. leucocephala*. In the dry season, carbohydrate tended to be higher in all the species than in the wet season (P<0.05). However, the wet season carbohydrate for *F. exasperata* was higher than that obtained in *L. leucocephala* and *B. papyrifera* (P<0.05). The lowest concentration of carbohydrate was recorded in *L. leucocephala* during the wet season. The carbohydrate composition in the forages ranged from 2.29%- 29.84% DM (Table 1).

Table 1: The effect of season on the mean (%) proximate composition of *B. papyrifera, F. exasperata and L. leucocephala*

FORAGE SPECIES	SEASONS	DM	CP	CF	NDF	ADF	EE	CHO
Broussonetia papyrifera	Dry	36.50**c**	20.52**d**	7.87**f**	34.76**a**	19.86**c**	6.07**c**	25.37**b**
	Wet	30.01**e**	27.17**b**	13.68**c**	32.14**c**	31.87**a**	6.45**a**	12.16**e**
Ficus exasperata	Dry	33.57**d**	18.39**e**	11.10**e**	33.84**b**	13.45**d**	3.89**d**	29.84**a**
	Wet	29.37**e**	27.16**b**	12.16**d**	25.58**f**	10.45**f**	3.82**e**	16.62**d**
Leucaena leucocephala	Dry	47.32**a**	24.14**c**	18.26**a**	31.28**d**	13.24**e**	3.87**d**	21.49**c**
	Wet	40.92**b**	30.06**a**	14.17**b**	27.74**e**	22.14**b**	6.13**b**	2.29**f**
SEM		**0.35**	**0.01**	**0.14**	**0.04**	**0.04**	**0.02**	**0.01**

Means in the same column followed by the same lowercase letters (**a, b**) are not significantly different at 5% significance level.

DM = Dry Matter. **CP** = Crude Protein. **CF** = Crude Fiber. **NDF** = Neutral Detergent Fiber. **ADF =** Acid Detergent Fiber

EE = Ether Extract **CHO =** Carbohydrate **SEM =** Standard Error of the Mean.

3.2 Effect of season on lignin and CT concentrations and IVOMD of the three forage species

The lignin concentration in *L. leucocephala* during the dry season was the highest and was similar (P<0.05) to that of *B. papyrifera* and *F. exasperata*. Lignin in the dry season, therefore, tended to be higher (P<0.05) in all the species than in the wet season. The lignin concentration for *F. exasperata* and *L. leucocephala* in the wet season were not statistically different (P>0.05). The least concentration of lignin was obtained in *B. papyrifera* during the wet season. The lignin composition in the forages ranged from 5.64% - 13.91% DM (Table 2).

The condensed tannin (CT) concentration in *B. papyrifera* was higher (P<0.05) than that obtained in *F. exasperata* and *L. leucocephala*. The concentrations of CT in *B. papyrifera* and *L. leucocephala* tended to be higher in the dry season than the wet season (P<0.05). In both the dry and wet seasons, *L. leucocephala* had similar CT concentrations (P<0.05). The lowest CT concentration was obtained in *F. exasperata* during the dry season. The CT values for the investigated forage species varied from 1.73% DM for *F. exasperata* to 7.09% DM for *B. papyrifera* (Table 2). The *in vitro* organic matter digestibility (IVOMD) in *F. exasperata* in the wet season was the highest amongst the three investigated species (P<0.05). During the year, *B. papyrifera* and *L. leucocephala* recorded their highest IVOMD level during the dry season. However, *B. papyrifera* had the lowest IVOMD among the species studied during the wet season. The IVOMD concentration ranged from 49.64% DM for *B. papyrifera* to 52.89% DM for *F. exasperata* (Table 2).

Table 2: The effect of season on the mean (%) of CT and lignin concentrations and IVOMD of forage species studied

FORAGE SPECIES	SEASONS	Lignin	CT	IVOMD
Broussonetia papyrifera	Dry	13.22**a**	7.09**a**	50.88**c**
	Wet	5.64**c**	6.96**b**	49.64**f**
Ficus exasperata	Dry	12.21**a**	1.73**e**	52.10**b**
	Wet	8.99**b**	2.65**d**	52.89**a**
Leucaena leucocephala	Dry	13.91**a**	4.18**c**	50.46**d**
	Wet	8.85**b**	3.85**c**	49.76**e**
SEM		**0.49**	**0.16**	**0.02**

Means in the same column followed by the same lowercase letters (**a, b**) are not significantly different at 5% significance level.

CT= Condensed Tannin **IVOMD** = *in vitro* Organic Matter Digestibility **SEM** = Standard Error of the Mean

3.3 Effect of season on mineral composition of the three forage species

The mean values of the mineral compositions of the investigated species during the dry and wet season's assessments are presented in Table 3. The ash concentration in *F. exasperata* was more than that obtained in *B. papyrifera* and *L. leucocephala* (P<0.05). Ash in the dry season appeared to be higher (P<0.05) in all the forage species than in the wet season. *Leucaena leucocephala* recorded the lowest concentrations of ash in both dry and wet seasons. However, *F. exasperata* recorded the highest concentrations of ash in both the dry and wet seasons. The ash composition in the forages ranged from 6.33% - 14.31% DM (Table 3).

The calcium concentration was highest in *F. exasperata* than that obtained in *B. papyrifera* and *L. leucocephala* (P<0.05). Calcium concentration for *B. papyrifera* and *L. leucocephala* appeared to be higher in the dry season than the wet season. However, the wet season calcium for *F. exasperata* was higher than that of *B. papyrifera* and *L. leucocephala* (P<0.05). The concentration of calcium in *B. papyrifera* during the wet season is not significantly different from that of *L. leucocephala* in the dry season (P>0.05). Similarly, the concentration of calcium in *B. papyrifera* during the dry season is similar to that of *F. exasperata* in the same season (P<0.05). The lowest concentration of calcium was obtained in *L. leucocephala* during the wet season. The calcium composition in the forages ranged from 1.24% - 4.01% DM (Table 3).

The phosphorus concentrations in all the investigated species were not significantly different across the seasons, with the exception of *L. leucocephala* in the wet season which was statistically different (P<0.05). *Leucaena leucocephala* in the wet season also recorded the lowest concentration of phosphorus. The phosphorus concentrations in the forages ranged from 0.14% - 0.25% DM (Table 3). The potassium concentration in *B. papyrifera* during the wet season was the highest (P<0.05). However, this was similar to those of *B. papyrifera* and *L. leucocephala* in the dry season. The lowest concentration was recorded in *L. leucocephala* during the wet season which was not significantly different with *F. exasperata* in both dry and wet seasons (P>0.05). The potassium composition in the forages ranged from 0.46% - 0.73% DM (Table 3).

Magnesium concentration was highest in *B. papyrifera* during the dry season than *F. exasperata* and *L. leucocephala* across the seasons (P<0.05). *Broussonetia papyrifera* appeared to have also recorded the lowest concentration of magnesium during the wet season. The magnesium concentration of *B. papyrifera* in the wet season, however, was not significantly different from *F. exasperata* and *L. leucocephala* across the seasons (P>0.05). The magnesium concentration in the forages ranged from 0.46% - 0.86% DM (Table 3).

Table 3: The effect of season on the mean (%) mineral concentration of the forage species studied

SPECIES	SEASONS	Ash	Ca	P	K	Mg
Broussonetia papyrifera	Dry	11.54**b**	2.54**b**	0.23**a**	0.72**a**	0.86**a**
	Wet	10.53**d**	1.95**c**	0.22**a**	0.73**a**	0.46**b**
Ficus exasperata	Dry	14.31**a**	2.53**b**	0.20**a**	0.50**b**	0.49**b**
	Wet	10.97**c**	4.01**a**	0.25**a**	0.52**b**	0.54**b**
Leucaena leucocephala	Dry	8.28**e**	1.94**c**	0.22**a**	0.69**a**	0.54**b**
	Wet	6.33**f**	1.24**d**	0.14**b**	0.46**b**	0.53**b**
SEM		**0.04**	**0.61**	**0.01**	**0.70**	**0.03**

Means in the same column followed by the same lowercase letters (**a, b**) are not significantly different at 5% significance level.
Ca = Calcium **P** = Phosphorus **K** = Potassium **Mg** = Magnesium
SEM = Standard Error of the Mean

4.0 Discussion

4.1 Effect of season on nutritive value of the forage species

The results for the proximate analysis showed that all the three forages had high dry matter (DM) content across the seasons. This is an indication that the forage species analysed constitute important, useful and dependable sources of DM for feeding ruminant livestock. The high DM content which is an indication of low moisture content, show a better storage potential since high moisture content is associated with increase of microbial activities during storage which reduces nutritional value of feed material (Abdullahi, 2000). The high dry matter content for all the species during the dry season compared to the wet season might probably be due to the dilution effect and translocation of pre-stored reserves in the plants during the wet season. Further, increase in solar radiation leading to higher evapo-transpiration of water in the plant material might partly contribute to the increase in dry matter content during the dry season.

Proteins constitutes a principal component of the animal body and are continuously needed in the feed for repair and synthetic process, hence they are vital for animal maintenance, growth and production (NAP, 1981). The crude protein contents generally obtained for all species fell within and above the ranges of 11%-20% (Larbi *et al.*, 1993) similar to that reported for browses of Southern Nigeria. Also the crude protein contents obtained for all the species were higher than the 12.5% reported for West African browse plants (Le Houerou, 1980). *Leucaena leucocephala*, consistently had a higher crude protein concentration compared to the other two forages, presumably because it is a legume whilst *B. papyrifera* and *F. exasperata* are non-leguminous. Msangi and Hardesty (1993) also reported that *L. leucocephala*, a legume, had higher nitrogen concentration than the native non-leguminous species.

The results of the study also indicate that the protein content of the samples for all the seasons is adequate for meeting the maintenance requirement of small ruminants (8.9% DM) Norton (2003). The values are also above the 10.0% DM set by US National Research Council as maintenance requirement for sheep and goats (Oladotun *et al.*, 2003). With all the forages having crude protein contents generally higher than 8%, below which Norton (2003) observed that feeds will not provide the required levels of ammonia for optimum rumen microbial activity is suggestive of the fact that these forages could be of high nutritional quality across the seasons. As well, these values were observed to be higher than the 13.0%-14.0% required for high producing animals (Meissner, 1997). Skerman (1977) reported that the principal value of browse is its high protein content in the dry season as evidenced in this research. Generally, the protein content of *B. papyrifera* is sufficiently high to affirm consideration of their use as plant protein sources in animal rations as high protein content in food if fully utilized by the body, will favour weight gain and animal performance. Cook *et al.* (1977) found that digestible crude protein was the most closely associated with animal response when single nutrients were considered. The high crude protein in all the forages during the wet season is, therefore, an indication of good quality during the season. Holechek *et al.* (1998) reported that the levels of cell solubles, crude protein and phosphorus are highest in actively growing forages and show substaintial declines as plants become dormant. This assertion confirms the observation made in the study.

Leucaena leucocephala, which was the most preferred and palatable forage species in this study was relatively high in fibre content during the wet and dry seasons. Crude fiber is negatively correlated with intake (McDonald *et al*., 1995). Low fiber content could stimulate increased feed intake as well as enhance the quality and digestibility of the feed as reported by Shiawoya *et al.* (2003). In this study, *B. papyrifera*, which was least palatable also appeared to be the least fibrous.

With regard to cell wall content, Sanon (2007) found a range of 31%-57% DM of NDF and 19%-43% DM of ADF. The values in the present study fall within the range obtained by Sanon (2007) and also Fall (1993). The NDF levels of species in this study were lower than the safe upper limit of 60% DM (Meissner *et al*., 1991) for guaranteed forage intake by sheep. The variation in the NDF levels in the examined forages did not vary widely in contrast with the report by Hove *et al*. (2001). However, the relatively low NDF concentration of *L. leucocephala* and *F. exasperata,* which indicated high quality feed, suggested high potential intake (Kilcher, 1981) compared to *B. papyrifera*, and these species also had the highest digestibility of the three species. The NDF of forage not only represents its functionality in promoting digestive function, but it also represents the character of the forage that can limit energy intake, and thus have a negative influence on performance of animals (Jeffries, 1990).

The least preferred and least palatable browse species, *B. papyrifera*, had higher values of ether extract than the most preferred species across the seasons. However, the values of the most preferred species for the two seasons (3.87% and 6.13% DM) are higher than the values of 3.6% and 4.2% reported for browses for West Africa (Le Houerou, 1980). The values 6.07%-6.45% for *B. papyrifera* compared favourably with the report of Le Houerou (1980). Okoli *et al.* (2001) also reported a range of 0.95%-5.3% DM which, however, is lower than the present result. Carbohydrate content of all the forages in the dry season was relatively higher than the wet season. However, *L. leucocephala* recorded quite low carbohydrate content in the wet season as compared to the other two species making it probably less energy efficient during the wet season. Generally, the high ether extract and carbohydrate contents of the tested species make the forages a good source of energy to the ruminants.

The ash content of the moderately preferred plant, *F. exasperata*, was comparatively higher than the values obtained for the highly preferred and least preferred plants. The 10.53%-11.54% DM and 10.97%-14.31% DM values obtained for *B. papyrifera* and *F. exasperata* respectively in this study compared favourably with the values of 10.90% DM reported for West Africa (Le Houerou, 1980) but also higher than 6.29% (Mecha and Adegbola, 1985) and a range of 3.0- 9.6% (Okoli *et al*., 2001) reported for Southeast Nigerian browses.

The concentration of calcium in the highly preferred plant (1.24%-1.94%) was comparatively lower than the levels obtained in the moderately and least preferred plants. The phosphorus concentrations in the browse species were fairly similar but generally the plants contained higher concentration of calcium than phosphorus across the seasons. Ibeawuchi *et al*. (2002) reported that the calcium content of browse plants is usually higher than that of phosphorus. Forage calcium/phosphorus ratios from 1:1 to 2:1 have been considered optimal, although in many arid areas this ratio is much higher. The low phosphorus value is of significant importance as calcium is closely related to phosphorus metabolism in the formation of bones with the tolerable limits of Ca: P ratio being in the range of 1:1 to 7:1 (Kallah *et al*., 2000). The Ca: P ratios of 11:1; 8:1 and 12:1 obtained for *B. papyrifera, L. leucocephala* and *F. exasperata* respectively in this study for the dry season assessment were, therefore, lower than the optimum level required for the effective utilization of these minerals in forages. Again the findings of the wet season study, 9:1, 9:1 and 16:1 obtained for *B. papyrifera, L. leucocephala* and *F. exasperata* respectively are inadequate for animals. Although these ranges are at variance with desired ratio, the deficiency can be corrected by mineral supplementation. Contrary to the above ratios, the calcium contents of 1.95%-2.54% DM and phosphorus contents of 0.22%-0.23% DM in *B. papyrifera* provide adequate requirements for animal performance as reported by NRC (1980) that 0.21%-0.52% in calcium and 0.16-0.37% in phosphorus are adequate for goats. Again, the levels of calcium and phosphorus presented in this study meet the recommended dietary requirements of ruminants indicating good source of minerals (Khanal and Subba, 2001).

The browse species evaluated had levels of potassium ranging from 0.46%-0.73% DM which fell within those reported by Aganga *et al*. (1999) and NRC (1975) (0.50% DM). The browse species in this study had low levels (0.46%-0.86% DM) of magnesium which would therefore, not meet the minimum requirement of 0.9%-1.8% DM for lactating sheep and goats (Aganga *et al*., 1999). However, NRC (1975) reported magnesium concentration of 0.04%-0.08% DM as a requirement for sheep. Dixon and Egan (1987) reported that during the dry season, the natural pastures and crop residues available for animals after crop harvest are usually fibrous and devoid of most essential nutrients which are required for improved microbial fermentation and improved performance of host animal. However, the results of the investigation run contrary to this assertion as quantities of forage consumed between seasons is not significant in most instances.

4.2 Effect of season on digestibility of the forage species

The *in vitro* technique which provides a comparative estimate of dry matter digestibility (DMD) and can rank the quality of feeds was used in this study. However, the significance of the method is limited as it does not take into account the intake of forage by the animal. The values obtained for the forages are, however, lower than the range of 54.0% -70.0% DM obtained for Ghana browse plants (Carew *et al*., 1980). This disparity in values may arise due to differences in diversity and composition of browse or perhaps due to differences in analytical methods. The present values were derived from regression equation (Y=57.49 -0.232X - 0.725ZX (Gerri and

Sottini, 1970) where Y= the true IVOMD, X= Crude fibre and Z= Ether extract.

The relatively low digestibility of *B. papyrifera* (49.64%-50.88% DM) may be due to relatively high NDF, ADF and condensed tannin contents. Low NDF content (20-35%DM) has been shown to result in high digestibility, while lignification of the plant cell wall decreases the digestibility of plant material in the rumen. The factors involved in the variation in digestibility among browse fodders include the concentration of nitrogen, cell wall content, especially lignin and tannins. Hence information on the NDF, ADF, lignin, and tannin content of foliage is essential for assessment of their digestibility (Norton, 1998).

The high IVOMD of *F. exasperata* compared to those of *B. papyrifera* and *L. leucocephala,* may be due to its relatively low NDF and low secondary metabolites, particularly condensed tannin (Oppong *et al*., 1997High condensed tannin (>50 g/kg DM) concentrations may reduce the digestibility of forages as a result of the N-CT complex formation that reduces their solubility and degradation by rumen bacteria (Waghorn *et al.,* 1990). The synthesis of condensed tannin and lignin in plant tissues involves, to a large extent common biochemical pathways (Swain, 1979). Consequently plants containing high levels of condensed tannin tend also to be highly lignified. This, however, was not the case in the study as *F. exasperata*, the highly digestible forage was also the highest lignified, particularly in the wet season. A low level of crude protein, less than 8.0% DM, is shown to depress digestibility as it is not sufficient to meet the needs of rumen bacteria (Norton, 1998). This does not apply in this experiment as the values obtained were higher than the recommended 8.0% DM.

4.3 Effect of season on condensed tannin (CT) concentration of the forage species

Broussonetia papyrifera, had relatively high condensed tannin concentration (6.96%-7.09% DM) throughout the seasons. In this study, *B. papyrifera,* with high level of condensed tannin also contain considerable high level of nutrients and minerals required for good animal performance.

Leucaena leucocephala and *F. exasperata* had considerable low concentrations of condensed tannin. Condensed tannins at low concentrations (20-40g/kg DM) are nutritionally beneficial through decreased degradation of dietary protein in the rumen and increased protein availability for digestion and absorption leading to good animal performance (Waghorn *et al*., 1990). Therefore, the level of condensed tannin in *B. papyrifera* may interfere with animal performance since they exceed 50g/kg DM. Topps (1993) stated that the phenolics appear to be the major constraint on the use of legume shrubs and trees for animal fodders because of their effect on intake, digestibility and the animal's performance. Nevertheless, it has been reported (Austin *et al*., 1989) that goats have the ability to overcome the difficulties due to detoxifying enzymes in the saliva.

5.0 Conclusion and Recommendations

Efforts to alleviate current constraints of inadequate and fluctuating feed supply to small ruminants in Ghana should be directed primarily toward a proper knowledge of the nutritional characteristics of various feed resources available in order to exploit their nutritional potential. Therefore, to achieve a more efficient system of green feeding it is necessary to introduce new field cropping species in ruminant nutrition as green forage in which nutritional value has not been evaluated. In this research analysis were conducted on nutritive value of an invasive species in Ghana, *B. papyrifera* and two known browse species.

In many cases during the study, the seasons of the experimental year did not cause a higher difference in nutrient content, between the treatments (forages) within a year. The common conclusion drawn regarding the value of *B. papyrifera* as a source of fodder for ruminants is that it is inadequate as the ruminant's sole source of nutrients. This is largely attributed to its condensed tannin content that has been shown to have an inverse relationship with voluntary intake, digestibility as well as palatability in ruminants. The potential of *B. papyrifera* as a supplementary feed should not be discounted because of its high condensed tannin concentration. With a cheaper source of plant crude protein, ether extract, carbohydrate, ash, calcium, phosphorus, potassium, magnesium and *in vitro* organic matter digestibility, *B. papyrifera* appears good potential forage in ruminant nutrition. With so many desirable attributes, both physically and nutritionally, of *B. papyrifera* as a fodder tree, one would surely consider it as a challenge to overcome its limitations in becoming a valuable source of feed. The utilization of *B. papyrifera* as a forage would control its widespread colonization of forest in the transition zone of Ghana and encourage livestock owning households to increase stock resulting in enhanced food nutritional value and cash flow. Further research is required on *B. papyrifera* to fully understand the factors affecting nutritive value. Examining the interactive effects of soil fertility, added nutrients, water (rainfall) and age of growth would be beneficial, as all of these factors affect nutritive value of *B. papyrifera*.

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