Effect of Bambara nut and cowpea intercropped with maize at different times on nutritive quality of maize for ruminant feeding

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Received: 24 February 2017. Accepted: 19 May 2017.

Abstract

Effects of Bambara nut and cowpea planted with maize at different times on nutritive quality of maize forage were investigated. The study was laid out in a Completely Randomized Design and the treatments were combination of crop types (Bambara nut-maize (MB) and Cowpea-maize (MC) and planting times of legumes (2 wks before planting maize, 2WBPM and 2 wks after planting maize, 2WAPM), and sole maize (as control). An experimental field measuring 19 m × 11 m was divided into 3 replicates; each replicate was sub-divided into 5 plots of dimension 3 m^2 each, with 1 m and 2 m inter-plots and inter-blocks spacing respectively. Maize forage samples were harvested on each plot at 10 wks after planting, oven-dried, milled and analyzed to evaluate the chemical composition, mineral composition, *in vitro* gas production and post-incubation characteristics. Results revealed significant differences ($P<0.05$) among treatments with the highest (95.00%) and least DM (92.12%) values were recorded for MB 2WBPM and MC 2WAPM, respectively. CP values ranged from 10.36% in MB 2WBPM to 15.67% in MC 2WBPM but not significantly different from 14.19 % recorded for sole maize. Ash ranged from 7.00% in MB 2WAPM to 10.00% in sole maize. MC 2WBPM and sole maize had the highest (50.63%) and least (38.40%) in ADF content ($P<0.05$). ADL value (7.25%) observed in MB 2WBPM was the highest, compared to the least (5.00%) in sole maize. Sole maize recorded the least (40.40%) and highest (25.91%) cellulose and hemicellulose contents, respectively while MC 2WAPM had the highest (50.88%) and lowest (15.80%) values for cellulose and hemicellulose, respectively. Ca content (4.55g/kg) of MB 2WAPM was lower than the other treatments. P content ranged from 3.54 g/kg in MB 2WAPM to 12.02 g/kg in MC 2WAPM. Gas production rates only varied ($P<0.05$) at the 3^{rd}, 6^{th}, 24^{th} and 48^{th} hours of incubation. MB 2WBPM yielded highest values of short chain fatty acids (0.09 µmol) and metabolizable energy (3.08 MJ/kg) while MB 2WAPM recorded the lowest values (0.01 µmol and 2.57 MJ/kg) for the same parameters. MC 2WAPM and MB 2WAPM produced highest values of OMD (31.60 %) and DMD (37.50 %), respectively. In conclusion, sole maize had desirable CP, Ca, P with least fibre constituents. OMD and DMD of the sole maize were not significantly different from most of the legume mixtures. Better SCFA and ME also make MB 2WBPM treatment desirable.

Keywords: Bambara nut, fibre fractions, *in vitro*, minerals, proximate.

Introduction

Nutrition is perhaps the most important consideration in livestock management and unavailability of adequate nutrition poses a major challenge to ruminant production. Forage is considered the cheapest major nutritional component in the diets of ruminant animals particularly in rural and sub-urban areas of the tropics (Akinsoyinu and Onwuka, 1988). Forages from a number of cereals grown for grain production, such as maize and wheat, are now important in the rations of ruminant animals (Leaver and Hill, 1992). Maize (*Zea mays*) is the third most important cereal crop of the world which is used as food, feed and forage. Maize fodder can safely be fed at all stages of growth without any danger (Dahmardeh *et al.*, 2009). Cereal-based forages are known to contain low protein content, with high potential as energy giving feedstuff for ruminants and monogastrics. While the use of N-fertilizer to improve grassland is uneconomical and could increase environmental related problems (Bamikole *et al.*, 2001) due to excessive release of nitrogenous compounds, intercropping of nitrogen-fixing legumes with other forage crops could be employed. Intercropping is growing of two or more crops simultaneously on the same piece of land within the same season in order to maximize beneficial interactions while minimizing companion crop competition (Sullivan, 2003; Poodineh et al., 2014). Intercropping activities are mostly targeted at high productivity and profitability (Yildirim and Guvence, 2005), improved soil fertility through addition of N fixing legumes (Hauggaard-Nielsen et al., 2001) and improved forage quality (Agegnehu et al., 2006). However, as the fixed nitrogen might be unavailable in the year of legume establishment, competition for available soil nutrients by the legumes and maize could influence the yield and nutritive quality of the maize forage. Therefore, the objective of this study was to evaluate the influence of the Cowpea (*Vigna unguiculata*) and Bambara nut (*Vigna subterranea*), and their planting times on the chemical composition, *in vitro* gas production, post-incubation parameters and mineral constituents of the companion crop, Maize (*Zea mays*).

Materials and Methods

Experimental sites

The field experiment was carried out at Umuahia, Abia state of Nigeria. Umuahia lies on latitude $5^0$32'N and longitude 7^0 29' E. It is located close to the rail road that lies between Port Harcourt to Umuahia South and Enugu city to its north. The laboratory analyses were carried out in the Department of Pasture and Range Management Laboratory, Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State. FUNAAB lies on latitude 7º 15' N, longitude 3.5º 25' E, at altitude of 140 m. Abeokuta lies in the derived savanna zone of Nigeria and has a bimodal rainfall pattern with peaks in June-July for early rain and October for late rain.

Land preparation, planting materials and plot management

The experimental land was ploughed and harrowed twice. An experimental field measuring 209 m^2 (19 m × 11 m) was divided into 3 replicates. Each block was sub-divided into 5 plots each of dimension 3 m × 3 m with 1 m inter-plots and 2 m inter-blocks spacing. Oba Super II maize variety was obtained from the National Seed Service Umudike, Umuahia, while Bambara and cowpea seeds were sourced from local markets in Umuahia and Okigwe, respectively. Planting was carried out in the month of July, 2012. Three seeds of maize per hole were sown on the control plots with 50 cm inter and intra-row spacing. For the intercropping, the legumes were planted either at 2 wks prior to or after maize planting, and they were drilled on separate rows, at the seed rate of 2 seeds/hole with 3 cm depth, 50 cm spacing between the maize and legume rows and 50 cm intra-row spacing. N.P.K 15: 15: 15 fertilizer at the rate of 200kg/ha was applied to all plots as basal application, irrespective of the treatments, at 4 wks after maize planting. Chemical weed control was carried out a day before sowing and this was complemented with manual weeding as necessary from 4 wks after planting.

Experimental design

The experiment was laid-out as a Completely Randomized Design which involved combination of two intercropping mixtures [(Bambara nut-maize (MB), Cowpea-maize (MC) and two planting times of the legumes, i.e. 2 wks before planting of maize (2WBPM) or 2 wks after planting of maize (2WAPM)] plus control (sole maize). So, the treatment combinations were MB 2WAPM, MB 2WBPM, MC 2WAPM, MB 2WBPM, and sole maize as control.

Harvesting/sampling for chemical analysis

Six stands of maize from each plot were randomly selected at 10 wks after planting and they were cut at 10 cm above ground level. Leaves and the succulent vegetative parts were then taken from these plants, oven-dried at 65^{o}C to constant weight and later milled for chemical analyses. The proximate composition of the samples was analyzed according to the procedure of AOAC (2000). Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were determined using the method of Van Soest *et al.* (1991). Cellulose and hemicellulose were derived by calculation from NDF, ADF and ADL as follows: Hemicellulose = NDF – ADF, Cellulose = ADF – ADL. For mineral composition, the samples were first taken through wet ashing prior to the determination of the mineral concentrations using an Atomic Absorption Spectrophotometer (Fritz and Schenk, 1979.

In vitro gas production

The *in vitro* gas production was determined following the procedure of Menke and Steingass (1988). Rate and extent of gas production were determined for each substrate from the non-linear regression equation: V (ml/200mg DM) = b $(1 - e^{-c\,(t-lag)})$; where Y= volume of gas produced at time 't', b= gas production from the insoluble fraction, c= gas production rate constant for the insoluble fraction and t = incubation time (Ǿrskov and McDonald, 1979). Organic matter digestibility (OMD), metabolizable energy (ME) and short chain fatty acids (SCFA) were calculated as: OMD= 14.88 + 0.889 GV + 0.45 CP + 0.651 ash (Menke and Steingass, 1988); ME= 2.20 + 0.1375 GV + 0.0057 CP + 0.0002859 EE^2 (Menke and Steingass, 1988); SCFA= 0.0239 GV - 0.0601 (Getachew *et al.*, 2000). After 72 hrs of incubation, the bottle contents were gently poured into pre-weighed crucibles which were oven-dried at 105°C for 24 hrs. The dry residues were weighed and *in vitro* dry matter digestibility (DMD) was thereafter calculated as:

$$\text{DMD (\%)} = \frac{\text{Initial DM input} - \text{DM residue} - \text{Blank}}{\text{Initial DM input}} \times 100$$

Statistical analysis

Data collected were subjected to one-way Analysis of Variance (ANOVA) and treatment means were separated using Duncan Multiple Range Test (DMRT) at 5% level of significance (SAS, 1999).

Results and Discussion

Table 1 reveals the influence of Cowpea and Bambara nut and their planting times on proximate composition and fibre contents of maize. The proximate composition (dry matter, crude protein, ash, ether extract and non-fibre carbohydrate) significantly varied (P<0.05). Higher (95.00%) and least DM (92.12%) values were recorded from MB 2WBPM and MC 2WAPM treatment combinations, respectively. CP values ranged from 10.36% in MB 2WBPM to 14.67% in MC 2WBPM and sole maize. Similarity (P>0.05) in the CP content of the sole maize (14.19%) and maize sown 2 wks later than cowpea (MC 2WBPM) (14.67%) might have indicated that the cowpea could not have commenced N-fixation, or the fixed N is unavailable at the time of harvesting in the intercrop and that the 2 treatments had only benefited from N supplied by the NPK fertilizer. It has been reported that the N_2-fixing ability of annual plants is usually characterized by a peak just after flowering (Dommergues and Ganry, 1985). Notwithstanding the treatments, the CP content of this study surpassed the NRC (1984) recommended minimum CP requirement (6%) of ruminant animals from tropical feeds and were higher than the minimum level of 7% required for optimum rumen function (Van Soest, 1994; Norton, 1994). Ash content of this study ranged from 7.00% in MB 2WAPM to 10.00% in sole maize. Since ash fraction of the proximate composition is regarded to contain all the minerals in the feed (AOAC, 2000), the higher ash value in the sole maize could be attributed to little or no competition for the available soil minerals on control plots when compared with the intercrop treatments. The fibre components comprise the major fraction of forage DM and the extent of its degradation by the rumen micro flora has important implications for forage digestibility and intake (Peterson et al., 1994). All fibre constituents, except neutral detergent fibre significantly varied (P<0.05); moreover, they were below the critical level of 75% at which feed intake is inhibited by NDF (Buxton, 1996). Higher ADF (50.63%) was recorded in MC 2WBPM, while the least (48.40%) was observed in the sole maize. There were variations (P<0.05) in the investigated minerals of the maize forage, except Na. (Table 2). Significantly least Ca (4.55g/kg) was recorded in MB 2WAPM, while similar values (7.29-8.09 g/kg) were recorded for the other treatments. Most of the treatments including sole maize influenced higher Ca content beyond the NRC (1985) recommended range (2-6g/kg) for cattle and sheep. Similarly, P ranged from 3.54 g/kg in MB 2WAPM to 12.02 g/kg in MC 2WAPM, and most treatments, except MB 2WAPM, encouraged P that surpassed the recommended (1.00-4.80 g/kg) requirements for different classes of ruminant animals (McDowell, 1992; 1997). Most Na results (0.99-1.15 g/kg) obtained in this study met the 1g/kg recommended for grazing animals (Underwood, 1981). Magnesium values of this study which ranged from 1.18 g/kg in MB 2WAPM to 3.11 g/kg in Sole maize, were within and beyond the recommended requirements (1.00-2.00 g/kg) of different classes of ruminant animals (McDowell, 1992; 1997). Cu also significantly (P<0.05) ranged from 4.00 mg/kg in MC 2WBPM to 11.00 mg/kg in MC 2WAPM. The Cu values, except 4.00 mg/kg in MC 2WBPM, were within the range (8-14 mg/kg) recommended for ruminants (NRC, 1984). The least (21.70

mg/kg) and higher (34.90 mg/kg) Mn were recorded for MB 2WAPM and MB 2WBPM respectively; and the range were lesser than critical level (35.00 mg/kg) of concentration for ruminants (Serra *et al.*, 1996). Generally, gas production is a function of degradable carbohydrates and therefore, the amount of gas depends on the nature of the carbohydrate (Blummel and Becker, 1997). Table 3 presents the gas production rates of the maize forage, and they only varied at the 3rd, 6th, 24th and 48th hr of incubation. SCFA, ME, OMD and DMD of the maize forage significantly differed (P<0.05) among the treatments (Table 4). MB 2WBPM recorded highest SCFA (0.09µmol) and ME (3.08 MJ/kg), while DMD ranged from 27.25% in MC 2WBPM to 37.50% in MB 2WAPM. Van Soest (1988) had reported that high NDF and ADL contents influenced low fibre digestion. Hence, the least DM digestibility of this trial could be linked to the high amount of NDF, lignin and cellulose amassed by the maize forage over the growing period.

Table 1: Effects of Bambara nut and Cowpea Maize mixtures planted at different times on proximate composition and fibre fraction of maize forage

Treatments	DM	CP	ASH	EE	NFC	NDF	ADF	ADL	HEM	CELL
					(%)					
Sole maize	92.50^{bc}	14.19^{a}	10.00^{a}	6.00^{bc}	6.48^{ab}	64.31	38.40^{b}	5.00^{b}	25.91^{a}	40.40^{c}
MB 2WAPM	92.62^{bc}	12.27^{ab}	7.00^{c}	6.62^{b}	5.40a^{b}	68.57	44.58^{ab}	6.75^{a}	23.99^{ab}	44.83^{abc}
MC 2WAPM	92.12^{c}	13.11^{ab}	8.37^{b}	6.25^{bc}	8.92^{a}	64.33	45.29^{ab}	5.25^{b}	21.93^{ab}	49.61^{ab}
MB 2WBPM	95.00^{a}	10.36^{b}	7.62^{bc}	5.00^{c}	7.28^{ab}	67.47	42.73^{b}	7.25^{a}	24.73^{a}	42.48^{bc}
MC 2WBPM	93.62^{b}	15.67^{a}	7.97^{b}	7.87^{a}	3.95^{b}	65.64	50.63^{a}	6.75^{a}	15.80^{b}	50.88^{a}
SEM	0.26	0.50	0.30	0.24	0.67	0.80	1.22	0.27	1.36	1.29

^{abc}: means on the same column with different superscripts are significantly varied (P < 0.05); SEM= Standard error of mean; DM: Dry matter; CP: Crude Protein; CF: Crude Fibre; EE: Ether Extract; ADL= Acid detergent lignin; ADF= Acid detergent fibre; NDF= Neutral Detergent Fibre; HEM= Hemicellulose; CELL= Cellulose; M= Maize; B= Bambara nut; C= Cowpea; 2WAPM= 2 Weeks before planting maize; 2WBPM= 2 Weeks after planting maize

Table 2: Effects of Bambara nut and Cowpea Maize mixtures planted at different times on the mineral levels (g/kg) of maize forage

Treatments	Ca	P	K	Na	Mg	Cu	Zn	Mn	Fe
			g/kg				mg/kg		
Sole maize	7.29^{a}	6.85^{bc}	10.70^{b}	1.09	3.11^{a}	7.5a^{bc}	33.00^{bc}	23.30^{bc}	92.00^{c}
MB 2WAPM	4.55^{b}	3.54^{c}	13.60^{ab}	0.99	1.18^{c}	9.5^{ab}	28.00^{cd}	21.70^{c}	95.00^{bc}
MC 2WAPM	7.68^{a}	12.02^{a}	18.70^{a}	1.07	2.02^{bc}	11.00^{a}	44.00^{a}	29.60^{ab}	101.50^{b}
MB 2WBPM	7.72^{a}	8.56^{bc}	12.90^{ab}	1.15	2.28^{b}	6.00^{bc}	24.50^{d}	34.90^{a}	101.00^{b}
MC 2WBPM	8.09^{a}	11.18^{b}	7.60^{b}	1.12	3.07^{a}	4.00^{c}	36.50^{b}	31.80^{a}	112.50^{a}
SEM	0.27	0.97	1.19	0.06	0.12	0.20	1.18	0.80	1.44

$^{a\ b,c}$: means on the same column with different superscripts are significantly varied ($P < 0.05$); SEM: Standard error of means; Ca= Calcium; P= Phoshorus; K= Potassium; Na= Sodium; Mg= Magnesium; Cu; Copper; Zn= Zinc; Mn= Manganese; Fe= Iron; M= Maize; B= Bambara nut; C= Cowpea; 2WAPM= 2 Weeks before planting maize; 2WBPM= 2 Weeks after planting maize

Table 3: Effects of Bambara nut and Cowpea Maize mixtures planted at different times on the *in vitro* gas production (ml/hr) of maize forage

Treatments	3	6	9	12	18	24	30	36	42	48	54	60	66	72
							Period of incubation (h)							
Sole maize	2.50^{a}	1.75^{ab}	2.50	2.25	2.50	3.00^{bc}	5.50	9.00	9.50	9.75^{ab}	8.00	7.50	8.75	3.75
MB 2WAPM	2.00^{b}	2.25^{ab}	2.75	5.00	4.25	2.75^{c}	6.00	6.00	7.50	7.00^{ab}	8.25	5.25	8.50	3.25
MC 2WAPM	0.75^{c}	4.00^{a}	3.00	4.25	3.50	6.00^{ab}	10.00	9.50	8.25	11.50^{a}	9.50	5.75	6.25	4.75
MB 2WBPM	2.25^{ab}	1.00^{b}	3.75	3.50	4.50	6.50^{a}	8.00	9.50	9.50	5.25^{b}	8.75	5.75	6.50	4.25
MC 2WBPM	2.50^{a}	1.75^{b}	4.00	3.25	3.50	4.75^{abc}	5.75	7.50	7.50	8.75^{ab}	8.50	5.00	5.25	4.00
SEM	0.40	0.30	0.22	0.45	0.43	0.55	0.77	0.70	0.81	0.78	0.60	0.41	0.60	0.69

^{a,b,c}: Means in same column with different superscripts are significantly ($p<0.05$) different; SEM = Standard error of means; 2WAPM= Two weeks after planting maize; 2WBPM= Two weeks before planting; M= Maize; B= Bambara nut; C= Cowpea.

Table 4: Effects of Bambara nut and Cowpea Maize mixtures planted at different times on the fermentation kinetics and post-incubation parameters of maize forage

Treatments	b (ml/200mgDM)	C (ml/hr)	Lag time (h)	SCFA (μmol)	ME (MJ/kg)	OMD (%)	DMD (%)
Sole maize	15.55	0.41	1.27	0.01^{bc}	2.61^{bc}	30.45^{a}	33.00^{ab}
MB 2WAPM	15.55	0.58	1.27	0.01^{c}	2.57^{c}	27.40^{b}	37.50^{a}
MC 2WAPM	15.55	0.53	1.26	0.08^{ab}	3.01^{ab}	31.60^{a}	33.25^{ab}
MB 2WBPM	15.55	0.45	1.25	0.09^{a}	3.08^{a}	30.28^{a}	29.25^{b}
MC 2WBPM	15.55	0.43	1.22	0.05^{abc}	2.84^{abc}	31.34^{a}	27.25^{b}
SEM	0.03	0.08	0.03	0.01	0.04	0.48	1.23

$^{a\ b,c}$: means on the same column with different superscripts are significantly varied ($P < 0.05$);
SEM= standard error of mean; b= fermentation of the insoluble fraction (mL/hr); c= gas production rate constant (h^{-1}); SCFA= short chain fatty acid; OMD= organic matter digestibility; ME= metabolisable energy; DMD= Dry matter digestibility; MJ/Kg DM= mega joule per kilogram dry matter; M= Maize; B= Bambara nut; C= Cowpea; 2WAPM= 2 Weeks before planting maize; 2WBPM= 2 Weeks after planting maize.

Conclusion

Maize planted 2 wks after cowpea (MC 2WBPM) and sole maize had the highest CP, while Sole maize possessed the least ADF, ADL, cellulose and highest hemicellulose. Sole maize recorded highest Mg, MC 2WAPM had better K and P; however, all treatments other than MB 2WAPM were noted for higher Ca content. MB 2WBPM was observed to be the highest for SCFA and ME, while MC 2WAPM and MC 2WBPM recorded the highest values for OMD and DMD, respectively. OMD and DMD of sole maize were high and similar to those observed in most of the legume mixtures.

For the production of high nutritive quality forage in terms of crude protein, fibre fraction, Ca and Mg with better digestibility, planting of sole maize is highly recommended based on the outcomes of this study.

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