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EFFECTS OF DRIED YELLOW CASHEW PULP IN DIETS OF WEST AFRICAN DWARF GOATS ON *IN VITRO* FERMENTATION PARAMETERS, VOLUME OF GAS PRODUCED AND FERMENTATION CHARACTERISTICS

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Abstract

Twenty growing West African Dwarf (WAD) goats aged 6-7 months, with an average initial weight of 6.42kg were randomly assigned to four treatments; containing 0 (control), 10, 20 and 30 % dried cashew pulp coded as T_1, T_2, T_3 and T_4, respectively. Each treatment had five experimental units. The effect of *in vitro* fermentation on first gas (a), potential gas production (b), potentially degradable fraction (a+b), rate of gas production (c), organic matter digestibility (OMD), metabolisable energy (ME), short chain fatty acids (SCFAs), methane (CH_4) production and *in vitro* gas production (IVGP) of the experimental diets were studied. Completely randomized design was used and data obtained were subjected to Analysis of Variance (ANOVA) and means that were significantly different were separated using LSD. Results showed that for the treatments, *in vitro* gas production for incubation periods of 6 hours was significant ($P < 0.05$), while those for 9, 12, 15, 18 and 24 hours were highly significant ($P < 0.01$). Values of IVGP, ME, OMD, SCFA and Methane for the treatments were highly significant ($P < 0.01$). Apart from the values for first gas produced, all the other fermentation characteristics for the treatments were highly significantly affected ($P < 0.01$) by the levels of inclusion of cashew pulp meal. The results also showed that T_1, T_2 and T_3 were not different from each other in *in vitro* gas production (at 24hrs), ME, OMD and SCFA, hence the diets containing sun-dried cashew pulp meal performed similarly with the control diet.

Key words: *In vitro*, yellow cashew pulp, volume of gas, incubation time, Methane

Introduction

In Nigeria, cashew grows successfully in virtually all agro-ecological zones including the semi-arid areas but with high concentration in the middle belt areas in smallholder farms and plantations. Cashew production comes from over twenty (20) States. These include: Anambra, Benue, Cross River, Edo, Enugu, Imo, Kebbi, Kogi, Kwara, Nassarawa, Ogun, Ondo, Osun, Oyo, Plateau and Sokoto among others (Ezeagu, 2002).

Cashew pulp is considered as a waste in cashew nut processing industry. Although there is growing awareness surrounding the economic importance of cashew production in Asian and African countries, the present practice in most established large-scale plantations is to allow the apples to fall from the trees naturally before harvesting the nuts. This contributes a gross waste of this versatile cashew product (Shuklajasha *et al*., 2006).When these fruits (pulp) are dried, they turn brown due to the effect of heat on them and these can be incorporated in animal feed since it is in abundance in the study area and is left to constitute environmental menace as it is left to litter the surrounding (Okpanachi *et al*., 2016).

The West African Dwarf goats are predominantly indigenous breeds found in Southern Nigeria (Odeyinka, 2000), where it makes significant contributions to the livelihoods of impoverished families. The potentials of WAD goats in poverty alleviation programmes are well-recognized, but are still largely untapped. This breed is known to display a wide range of qualitative variations in coat colour: black, brown, white, pied, mottled, mixed, etc (Odubote 1994a; Ozoje and Mbgere, 2002), presence or absence of wattles (none, unilateral or bilateral) and super-numerary (extra) teats in adult females (which could be two, three or four extra teats (Odubote, 1994b).

Ruminants (beef, dairy, goats, and sheep) are the main contributors to greenhouse gases production (GHG) which lead to changes in the chemical composition of the atmosphere. These gases which cause greenhouse effect include: methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), sulphur dioxide (SO_2), ammonia (NH_3) and dust particles. Stats South Africa, (2010) reported that there are 13.7; 28.8 and 2 million herd of cattle, sheep and goats in South Africa, respectively. The 2001 population of livestock in Nigeria has been estimated to be 45.26 m goats, 118.59 m poultry, 28.69 m sheep, 15.60 m cattle, 5.25 m pigs and 1 m horses, camels and donkeys (NPC, 2004). This is against an estimation of 34.5 million goats, 170 million poultry, 22.1 million sheep, 14 million cattle and 3.4 million pigs (RIM, 1992).

The ruminant animal is unique because of its four stomach compartments: reticulum, rumen, omasum and abomasum. The rumen is a large, hollow muscular organ where microbial fermentation occurs. It can hold 40 to 60 gallons of material and an estimated 150 billion microorganisms per teaspoon are present in its contents. The function of the rumen as a fermentation vat and the presence of certain bacteria promote the development of gases. These gases are found in the upper part of the rumen with CO_2 and CH_4 making up the largest portion. The proportion of these gases is dependent on rumen ecology and fermentation balance. Typically, the proportion of carbon dioxide is two to three times that of CH_4, although a large quantity of CO_2 is reduced to CH_4. Approximately 132 to 264 gallons of ruminal gas produced by fermentation are belched each day. The eructation of gases via belching is important in bloat prevention but is also the way CH_4 is emitted into the atmosphere.
According to Sniffen and Herdt (1991), the typical composition of rumen gases for Hydrogen, Oxygen, Nitrogen, Methane and carbon dioxide is 0.2%, 0.5%, 7.0%, 26.8% and 65.5% respectively.

Methane gas is an important gas among gases produced by ruminants at fermentation, and has been reported by Babayemi and Bamikole (2006) to have a negative effect on the animal, on one hand when methane gas accumulate in the rumen, it results in bloat and on the other hand it is an energy loss to the animals and when emitted it contributes to ozone layer destruction. Although gas production is nutritionally a wasteful effort, it provides a useful basis from which metabolizable energy (ME), organic matter digestibility (OMD) and short chain fatty acids (SCFA) may be predicted (Babayemi *et al*., 2009).
Methane production from ruminants is affected by the type of feed consumed (Theart, 2015). The amount of methane produced by livestock depends on their size, age, digestive system and quality and quantity of feed intake. For instance, buffalo, cattle, camels, goats and sheep emit the greatest quantities of methane: 25-118 kg / head/ annum for cattle, and 5-8 kg/ head/ annum for small ruminants (IPCC, 1995) while, pseudo-ruminants (horses, donkeys and mules) and mono-gastric such as pigs and poultry produce less methane, since their digestion is not so dependent on enteric fermentation (Bourn *et al.*, 2005). Enteric methane from ruminants account for about 11-17% of methane generated globally (Beauchemin *et al*., 2009). In 2004, commercial beef cattle contributed 45% while emerging/communal cattle 33% of the total enteric fermentation of 1225 Giga gram (Gg) CH_4 in South Africa with mature cows and bulls having the highest CH_4 emission factors for enteric fermentation (Otter, 2010).

Okpanachi *et al.* (2016) conducted a research to determine the effects of two varieties (yellow and red) of dried cashew pulp on *in vitro* fermentation parameters and volume of *in vitro* gas produced at different incubation time. Results showed that *in vitro* gas production for 3 and 6 hours incubation periods for red sun-dried cashew pulp meal were significantly higher ($P < 0.01$) than those for yellow sun-dried cashew pulp meal. The value of sun-dried red cashew pulp meal for first gas was significantly higher ($P < 0.01$) than yellow cashew pulp. Metabolisable energy, organic matter digestibility, potential gas production and methane production of the sun-dried yellow cashew pulp meal were significantly higher ($P<0.05/P< 0.01$) than that of the red variety. However, Okpanachi *et al.* (2016) opined that even though the yellow variety produced a higher volume of methane gas (5.000 mL/200 mg DM methane) as compared to the red variety (3.000 mL/200 mg DM methane), it is a safe level and not as high as that produced by some forages which can be as high as 15.000 – 20.000 mL/200 mg DM methane. Overall result of the study showed that the yellow cashew pulp meal was richer and better than the red variety.
Although, it has been established that cashew pulp is a very cheap feedstuff for ruminants which is also abundantly available especially during the dry season when fresh grass is not available for ruminants, considering the amount of green house gases released by ruminants when they are being fed, it is essential to also study the effect of feeding such cheap and available feedstuff to the environment. This research was therefore carried out to study the effects of graded levels of sundried yellow cashew pulp (SDYCP) in the diets of WAD goats on *in vitro* fermentation parameters, volume of gas produced at different incubation time and fermentation characteristics.

Materials and Methods

Experimental location and treatments

The experiment was conducted at the Sheep and Goat Unit of the Teaching and Research Farm of Kogi State University, Anyigba. The study site is located on Latitude 7°30'N and Longitude 7^0 09'E and with an average altitude of 42m above sea level. The area falls within tropical wet and dry climate region and savanna with average annual rainfall of 1600mm, the daily temperature range is 25^0C – 35^0C (Ifatimehin *et al.*, 2011). Twenty growing West African Dwarf (WAD) goats aged 6-7 months, with an average initial weight of 6.42kg were randomly assigned to four treatments; containing 0 (control), 10, 20 and 30 % dried cashew pulp coded as T_1, T_2, T_3 and T_4, respectively. Each treatment had five experimental units. The variation in the level of inclusion of some ingredients is to allow for iso-nitrogenous and iso-caloric experimental diets.

Preparation of cashew pulp

The yellow variety of cashew (*Anacardium occidentale*) pulp was obtained from Anyigba and its environs. They were washed, sliced with the aid of knives and chopping boards into bits, air-dried and moved to a screen house where they were properly dried. The dried cashew pulp were packaged, weighed milled and sent to Nigerian Institute of Animal Science Centre of Excellence, Animal Science Department, University of Benin for *in vitro* analysis.

In vitro fermentation parameters measured

In vitro fermentation techniques were carried out based on syringes (Menke *et al.*, 1979 and Blummel *et al.*, 1997) and the following parameters were measured:
(i). First gas (a) (ii). Potential gas production (b) (iii). Potential degradable fractions (a+b) (iv). Rate of gas production (c) (v). Organic matter digestibility (OMD) (vi). Metabolisable energy (ME) (vii). Short chain fatty acids (SCFAs) (viii). Methane (CH4) production (ix). *In vitro* gas production.

In vitro Gas Fermentation Procedure

Rumen fluid was collected from goats before they were fed in the morning as described by Babayemi and Bamikole (2006) using suction tube. The collected rumen fluid was filtered into a pre-warmed thermo flask at a temperature of 39°C using a cheese cloth. The buffer solution used consist of (g/litre) 9.8 $NaHCO_3$ + 2.77 $NaPO_4$ + 0.5 KCl + 0.47 NaCl + 2.16 $MgSO_4.7H_2O$ + 0.16 $CaCl_2.2H_2O$.
Incubation procedure was as reported by Menke and Steingass (1988) using 120ml calibrated transparent glass syringes fitted with silicon tube. Two hundred milligram (200 mg) of each sample (in triplicates) was loaded in the syringes. The rumen fluid and the buffer were mixed together in ratio of 1:4 (v/v). The 30 ml of the inoculum was drawn into 50 ml glass calibrated syringes; this was then dispensed into the calibrated transparent glass syringes containing the feed samples under continuous CO_2 flushing. Air bubbles were removed from the syringes by gently tapping them and pushing the piston upwards to expel the air. The silicon tubes on the syringes were properly clipped to prevent escape of gas before placement in the incubator. The glass syringes were placed in the incubator at a temperature of 39°C for 24 hours. Gas production was measured at 3, 6, 9, 12, 15, 18, 21 and 24 hours. At post incubation period, 4 mL of NaOH (10M) was introduced to estimate methane production as reported by Fievez *et al.* (2005). ME (MJ/Kg) and OMD were estimated as established by Menke and Steingass (1988), and SCFAs were calculated as reported by Getachew *et al.* (1999) 24 hours post incubation. The formulae used for calculations were:

$$ME = 2.20 + 0.136Gv – 0.057 CP + 0.0029CF$$
$$OMD = 14.88 + 0.889Gv + 0.45CP + 0.0651 XA$$
$$SCFA = 0.0239Gv – 0.0601$$

Where: Gv = Net gas production (MlL / 200 mg DM)
CP = Crude protein, CF = Crude fibre, XA = Ash
Other parameters such as: a, b, a+b and c were derived by calculation, where
a = First gas, b = potential gas production, a + b = Potential degradable fractions.
c = Rate of gas production.

Experimental design and statistical analysis

Completely randomized design was used. Data obtained were subjected to Analysis of Variance (ANOVA) and means that were significantly different ($P < 0.05$) were separated using Least Significant Difference (LSD), both contained in SPSS for Window, version 16.

Table 1: Gross Composition of Experimental Diets Fed to West African Dwarf Goats

	Experimental Diets			
Ingredients (%)	T_1 (0 %)	T_2 (10 %)	T_3 (20 %)	T_4 (30 %)
Cashew Pulp	0.00	10.00	20.00	30.00
Bambaranut Waste	28.80	18.00	13.50	8.00
Maize Offal	19.20	18.00	11.00	4.00
Rice Offal	3.00	3.00	4.50	6.00
Burukutu Waste	37.00	39.00	39.00	40.00
Oil Palm Sludge	6.00	6.00	6.00	6.00
Cassava Peel	3.00	3.00	3.00	3.00
Bone Meal	2.00	2.00	2.00	2.00
Salt	1.00	1.00	1.00	1.00
Total	**100**	**100**	**100**	**100**
Calculated values				
Crude Protein (%)	17.26	17.17	17.10	17.10
Crude Fibre (%)	16.76	16.11	16.06	16.05
ME (Kcal/Kg)	2513.91	2540.40	2575.49	2603.25

M E = Metabolisable Energy

Results

Volume of *in vitro* gas produced at different incubation time by diets containing graded levels of sun-dried cashew pulp meal.

Volume of *in vitro* gas produced at different incubation time by diets containing graded levels of sun-dried cashew pulp meal is presented in Table 2. *In vitro* gas production for incubation periods of 3 hours was not significant ($P > 0.05$). *In vitro* gas production for incubation periods of 6 hours was significant ($P < 0.05$), while those for 9, 12, 15, 18 and 24 hours were highly significant ($P < 0.01$). Values for 3 hours incubation period ranged from 8.50 (T_4) – 11.00 (T_3); 6 hours ranged from 15.50 (T_4) – 22.00 (T_3); 9 hours ranged from 15.50 (T_4) – 35.50 (T_1); 12 hours ranged from 17.00 (T_4) – 36.50 (T_1); 15 hours ranged from 17.00 (T_4) – 37.50 (T_1); 18 hours ranged from 20.00 (T_4) – 38.00 (T_1); 21 hours ranged from 22.00 (T_4) – 39.00 (T_3) and 24 hours ranged from 23.50 (T_4) – 39.00 (T_1).

Effect of *in vitro* fermentation on IVGP, ME, OMD, SCFA and methane of diets containing graded levels of sun-dried cashew pulp meal.

Results on IVGP, ME, OMD and SCFA of diets containing graded levels of sun-dried cashew pulp meal are presented in Table 3. All the *In vitro* parameters were highly significant ($P < 0.01$). Values for IVGP ranged from 23.500 (T_4) – 39.000 (T_1); ME ranged from 4.507 (T_4) – 6.731 (T_1); OMD ranged from 44.265 (T_4) – 57.949 (T_3); SCFA ranged from 0.502 (T_4) – 0.872 (T_1) and methane ranged from 10.500 (T_1 and T_2) – 39.000 (T_3).

In vitro gas production characteristics of diets containing graded levels of sun-dried cashew pulp meal.

In vitro gas production characteristics of T_1 – T_4 is presented in Table 4. Apart from the values for first gas, all the other fermentation characteristics were highly significant ($P < 0.01$). Values for first gas ranged from 8.500 (T_4) – 11.000 (T_3); potential degradable fraction ranged from 23.500 (T_4) – 39.00 (T_1 T_2 and T_3); potential gas production ranged from 15.000 (T_4) – 30.000 (T_2) and rate of gas production ranged from 0.020 (T_3) – 0.107 (T_1).

Table 2**:** Volume of *in vitro* gas at different incubation time by SDYCP containing diets

	Experimental Diets				
Incubation period (Hours)	**T_1 (0 %)**	**T_2 (10 %)**	**T_3 (20 %)**	**T_4 (30 %)**	**SEM**
3	9.50	9.00	11.00	8.50	0.38^{ns}
6	19.00^{ab}	18.00^{ab}	22.00^{a}	15.50^{c}	0.87^{*}
9	35.50^{a}	31.50^{c}	33.00^{ab}	15.50^{d}	2.41^{**}
12	36.50^{a}	33.50^{c}	34.50^{ab}	17.00^{d}	2.37^{**}
15	37.50^{a}	35.50^{a}	36.50^{a}	17.00^{b}	2.58^{**}
18	38.00^{a}	35.50^{a}	37.00^{a}	20.00^{b}	2.25^{**}
21	38.50^{a}	36.00^{a}	39.00^{a}	22.00^{b}	2.14^{**}
24	39.00^{a}	39.00^{a}	39.00^{a}	23.50^{b}	2.07^{**}

a, b, c, d = Means with different superscripts on the same row are significantly different.
SEM = Standard Error of Mean, * = significant at (P < 0.05), ns = not significant

Table 3: IVGP, ME, OMD, SCFA and methane of SDYCP containing diets

	Dietary Treatments				
***In Vitro* Parameters**	**T_1 (0 %)**	**T_2 (10 %)**	**T_3 (20 %)**	**T_4 (30 %)**	**SEM**
IVGP (mL/200 mg DM)	39.000^{a}	39.000^{a}	39.000^{a}	23.500^{b}	2.065^{**}
ME (MJ/Kg DM)	6.731^{a}	6.679^{a}	6.614^{a}	4.507^{b}	0.289^{**}
OMD (%)	57.322^{a}	57.458^{a}	57.949^{a}	44.265^{b}	1.777^{**}
SCFA (µmol)	0.872^{a}	0.872^{a}	0.872^{a}	0.502^{b}	0.049^{**}
Methane (mL/200 mg DM)	10.500^{c}	10.500^{c}	39.000^{a}	15.000^{b}	3.597^{**}

a, b, c = Means with different superscripts on the same row are significantly different (P < 0.01)
SEM = Standard Error of Mean, ** = significant at (P < 0.01)
IVGP - *In vitro* Gas Production (at 24hrs)
ME – Metabolisable Energy
OMD – Organic Matter Digestibility
SCFA – Short Chain Fatty Acids

Table 4: *In vitro* gas production characteristics of SDYCP containing diets

	Dietary Treatments				
Fermentation Characteristics	**T_1 (0 %)**	**T_2 (10 %)**	**T_3 (20 %)**	**T_4 (30 %)**	**SEM**
a	9.500	9.000	11.000	8.500	0.384^{ns}
b	29.500^{a}	30.000^{a}	28.000^{a}	15.000^{b}	1.908^{**}
a+b	39.000^{a}	39.000^{a}	39.000^{a}	23.500^{b}	2.065^{**}
c	0.107^{a}	0.028^{b}	0.020^{b}	0.096^{a}	0.012^{**}

a, b = Means with different superscripts on the same row are significantly different (P < 0.01)
SEM = Standard Error of Mean

Discussion

Volume of *in vitro* gas produced at different incubation time by diets containing graded levels of sun-dried cashew pulp meal.

The volume of *in vitro* gas produced at different incubation time by diets containing graded levels of sun-dried cashew pulp meal showed that *in vitro* gas production for incubation periods of 3 hours was not affected. This implied that the gas production between the treatments for the 3 hour duration made no difference in carbohydrate fermentation. Similar findings were also reported by Familade and Babayemi (2009). *In vitro* gas production for incubation periods of 6 hours was high, and those for 9, 12, 15, 18 and 24 hours were higher. During the 6 hour duration, the volume of gas produced for T_3 was higher than for the other treatments. Between 9 and 12 hours, volume of gas produced for T_1 was higher than for the other treatments. Between 15 and 24 hours, volume of gas produced for T_1, T_2 and T_3 were higher than for T_4. This means that more carbohydrate fermentation took place in treatments within these hours (Familade and Babayemi, 2009) and also that treatments containing sun-dried cashew pulp (especially T_2 and T_3) did not differ from the control diet which did not contain sun-dried cashew pulp. This could also imply that T_1, T_2 and T_3 had higher digestibility because *in vitro* gas production is an indication of the degradability of forage or feed sample (Abegunde *et al*., 2009). The *in vitro* gas production values (8.50 – 39.00 mL/200 mg DM) in this study fell within the range of 12.5 – 44.90 mL/200 mg DM reported by Arigbede *et al.* (2006) for multipurpose trees in Abeokuta, Nigeria.

Effect of *in vitro* fermentation on IVGP, ME, OMD, SCFA and methane of diets containing graded levels of sun-dried cashew pulp meal.

The values of IVGP, ME, OMD and SCFA in T_1, T_2 and T_3 were higher than that of T_4. Methane production in T_3 was significantly higher ($P < 0.01$) than those in T_1, T_2 and T_4. Akinfemi and Muktar (2012) who studied the changes in chemical composition and *in vitro* digestibility of fungal treated bagasse reported 5.53 MJ/Kg DM – 6.80 MJ/Kg DM, 38.77 % – 50.06 % and 0.56 µmol -0.75 µmol for ME, OMD and SCFA respectively for fungal treated bagasse. The ME (4.507 MJ/Kg DM – 6.731 MJ/Kg DM) obtained in this study for sun-dried cashew pulp meal falls within the range by Akinfemi and Muktar (2012) earlier reported. The OMD (44.265 % – 57.949 %) and SCFA (0.502 µmol – 0.872 µmol) obtained in this study for sun-dried cashew pulp meal are higher than those of Akinfemi and Muktar (2012) earlier reported. The results in this study show that T_1, T_2 and T_3 are not different from each other, hence the diets containing sun-dried cashew pulp meal performed similarly with the control diet. Their high gas production depicts better digestibility (Abegunde *et al*., 2010). Their being better *in vitro* gas production, metabolisable energy and short chain fatty acid allow for increased microbial activities as a result of increased pH (Sodeinde *et al*., 2008). The methane value obtained in this study ranged from 10.500 ml/200 mg DM – 39.000 mL/200 mg DM. The amount of methane produced by livestock depends on their size, age, digestive system and quality and quantity of feed intake. For instance, buffalo, cattle, camels, goats and sheep emit the greatest quantities of methane: 25-118 kg / head/ annum for cattle, and 5-8 kg/ head/ annum for small ruminants (IPCC, 1995) while, pseudo-ruminants (horses, donkeys and mules) and mono-gastrics such as pigs and poultry produce less methane, since their digestion is not so dependent on enteric fermentation (Bourn *et al.*, 2005).

***In vitro* gas production characteristics of diets containing graded levels of sun-dried cashew pulp meal.**

The non- significance of the first gas produced means that there was no difference in nutritive value among the treatments in the soluble fraction or carbohydrate. This work agreed with the reports of Sodeinde *et al*. (2008). Results of potential degradable fraction and potential gas production for T_1, T_2 and T_3 were statistically similar but higher than that for T_4. The result for the rate of gas production value shows that T_1 and T_4 were significantly similar just like T_2 and T_3 were. Results for T_1 and T_4 were however higher than those of T_2 and T_3. The results on potential degradable fraction and potential gas production in this study showed that digestibility and fermentable carbohydrate were higher for diets T_1, T_2 and T_3 than for diet T_4. Akinfemi and Muktar (2012) who studied the changes in chemical composition and *in vitro* digestibility of fungal treated bagasse reported15.00 – 19.00 and 0.012 mL / hr – 0.03 mL / hr for potential gas production and rate of gas production respectively. Similarly, the values in this study are higher than those of Akinfemi and Muktar (2012).

Conclusions

Between 15 and 24 hours, volume of gas produced for T_1, T_2 and T_3 were higher than for T_4. This means that more carbohydrate fermentation took place in treatments within these hours and also that treatments containing sun-dried cashew pulp (especially T_2 and T_3) did not differ from the control diet which did not contain sun-dried cashew pulp. This could also imply that T_1, T_2 and T_3 had higher digestibility because *in vitro* gas production is an indication of the degradability of forage or feed sample

The results also showed that T_1, T_2 and T_3 are not different from each other in *in vitro* gas production (at 24hrs), metabolisable energy, organic matter digestibility and short chain fatty acids, hence the diets containing sun-dried cashew pulp meal performed similarly with the control diet.

The results on potential degradable fraction and potential gas production in this study showed that digestibility and fermentable carbohydrate were higher for diets T_1, T_2 and T_3 than for diet T_4.Further research involving the use of higher levels of yellow cashew pulp is recommended.

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