Nutritive value of some crop residues and agricultural by-products at Aduwawa cattle market, Benin City, Nigeria

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Abstract

The production of ruminants in the tropics has been significantly hampered by the rising cost of feedstuffs, both in terms of quality and quantity. By lowering the cost and raising the nutritional quality and accessibility of feedstuffs, these feeding gap issues in the tropics can be resolved. Agricultural by-products and crop residues are readily available, less costly to source, and mostly highly fibrous by nature. Ruminants can digest fibrous feeds due to the presence of microorganisms in the rumen. This study was carried out to determine the chemical composition and in vitro fermentation characteristics of some crop residues and agricultural by-products sold at a cattle market in Benin City, Edo State, Nigeria. Crop residue included groundnut (Arachis hypogea L.), haulm (GDH), and by-products such as common bean (Phaseolus vulgaris) husk (BNH), wheat (Triticum aestivum L.) offal (WHO), pearl millet (Pennisetum glaucum) offal (MIL) and cotton seed (Gossypium herbaceum) offal (CSO) were evaluated. The feed materials were oven dried, milled, and evaluated for proximate composition using standard procedures. In vitro fermentation study was conducted for 24 h with gas production (methane) determined at 3 h intervals. Dry matter digestibility (DMD), fermentation efficiency (FE), short-chain free fatty acids (SCFA), metabolisable energy (ME), and organic matter digestibility (OMD) were also determined using standard procedures. The dry matter (DM) content was higher in WHO (94.00). Crude protein (CP) ranged from 4.66 to 15.75% with the higher value in WHO. Crude fibre (CF) ranged from 10.56 to 31.28% while ash content ranged between 5.93 and 22.95%. Ether extract (EE) content ranged from 7.99 to 28.98%. Total gas produced at 24 h of in vitro study was higher in wheat offal (48.00 mL) followed by groundnut haulms (43.33 mL). Methane production, dry matter digestibility (DMD), fermentation efficiency (FE), short chain free fatty acids (SCFA), metabolisable energy (ME), and organic matter digestibility (OMD) ranged from 17.33 to 23.00 mL, 43.83 to 64.80%, 1.13 to 1.18, 0.72 to 1.08, 7.24 to 9.62 MJ/Kg and 58.86 to 71.16% respectively. The crop residue (GDH) and agricultural by-products (WHO, CSO) with an appreciable level of crude protein and digestibility values could be good feed resources for feeding ruminant animals in critical periods of feed scarcity.

***Keywords:** ruminant feeding, crop residues, agricultural byproducts, in vitro fermentation, chemical composition.*

Resume

La production de ruminants sous les tropiques a été considérablement entravée par la hausse du coût des aliments pour animaux, tant en termes de qualité que de quantité. En abaissant le coût et en augmentant la qualité nutritionnelle et l'accessibilité des aliments pour animaux, ces

problèmes d'écart d'alimentation sous les tropiques peuvent être résolus. Les sous-produits agricoles et les résidus de cultures sont facilement disponibles, moins coûteux à la source et pour la plupart très fibreux par nature. Les ruminants peuvent digérer les aliments fibreux en raison de la présence de bactéries fibrolytiques. Cette étude a été réalisée pour déterminer la composition chimique et les caractéristiques de fermentation in vitro de certains résidus de cultures et sous-produits agricoles vendus sur un marché aux bestiaux à Benin City, dans l'État d'Edo, au Nigéria. Les résidus de culture comprenaient l'arachide (Arachis hypogea L.), le haulm (GDH) et des sous-produits tels que l'enveloppe de haricot commun (Phaseolus vulgaris) (BNH), les abats de blé (Triticum aestivum L) (OMS), les abats de millet perlé (Pennisetum glaucum) (MIL) et les abats de graines de coton (Gossypium herbaceum) (CSO) ont été évalués. Les matières premières ont été séchées au four, broyées et évaluées pour une composition immédiate à l'aide de procédures standard. Une étude de fermentation in vitro a été menée pendant 24 h avec une production de gaz (méthane) déterminée à 3 h d'intervalle. La digestibilité de la matière sèche(DMD), l'efficacité de la fermentation (FE), les acides gras libres à chaîne courte (AGCC), l'énergie métabolisable (ME) et la digestibilité de la matière organique (OMD) ont également été déterminées à l'aide de procédures standard. La teneur en matière sèche (DM) était plus élevée à l'OMS (94,00). La teneur en protéines brutes (PC) variait de 4,66 à 15,75%, la valeur la plus élevée à l'OMS. Les fibres brutes (CF) variaient de 10,56 à 31,28% tandis que la teneur en cendres variait entre 5,93 et 22,95%. La teneur en extrait d'éther (EE) variait de 7,99 à 28,98%. Le gaz total produit après 24 h d'étude in vitro était plus élevé dans les abats de blé (48,00 mL) suivis des grains d'arachides (43,33 mL). La production de méthane, la digestibilité de la matière sèche (DMD), l'efficacité de la fermentation (FE), les acides gras libres à chaîne courte (AGCC), l'énergie métabolisable (ME) et la digestibilité de la matière organique (OMD) variaient de 17,33 à 23,00 mL, 43,83 à 64,80%, 1,13 à 1,18, 0,72 à 1,08, 7,24 à 9,62 MJ/Kg et 58,86 à 71,16% respectivement. Les résidus de culture (GDH) et les sous-produits agricoles (OMS, OSC) avec un niveau appréciable de protéines brutes et des valeurs de digestibilité pourraient constituer de bonnes ressources alimentaires pour nourrir les ruminants pendant les périodes critiques de pénurie d'aliments pour animaux.

***Mots clés**: alimentation des ruminants, résidus de cultures, sous-produits agricoles, fermentation in vitro, composition chimique*

الملخـــص

من ، الحيوانـــات علـف تكلفـــة ارتفـــاع بســـبب كبـــير بشـــكل المداريـــة المنـــاطق فـي المجـــترات إنتـــاج تعرقـــل وقـد ، الحيوانـــات علـف إلـى الوصـــول وإمكانيـــة الغذائيـــة الجـودة وزيـــادة التكلفـــة خفـض خـلال من .والكميـــة الجـودة حيـث ومخلفـــات الزراعيـــة الثانويـــة تجـاتالمـن .الاســـتوائية المنـــاطق فـي هـذه التغذيـــة فجـوة مشـاكل حل يمكـن للحيوانـــات يمكـن .بطبيعتـــه ليفـــي معظمهـا وفـي المصـــدر فـي تكلفـــة وأقـل ، بســـهولة متاحـة المحاصـــيل التركيـــب لتحديـــد الدراســة هـذه أجريـت .الليفيـــة البكتيريـــا وجود بســـبب الليفـــي الطعـام هضـم المجـــترة الـــتي الزراعيـــة الثانويـــة والمنتجـــات اصـيلالمـح مخلفـات لبعـض المختـــبر فـي التخمـــير وخصـائص الكيميـــائي

السوداني الفول المحاصيل بقايا وشملت .بنيجيريا إيدو بولاية بنين مدينة في للماشية سوق في تباع (فولغاريس فاسيولوس) الشائع الفول قشر مثل الثانوية والمنتجات (غ) والهولم ، (.ل هايبوجيا أراشيس) (جلاوكوم بينيسيتوم) اللؤلؤي الدخن ومخلفات ، (أومز) (ل إيستيفوم تريتيكوم) القمح ومخلفات ، (بن) الخام المواد تجفيف تم .(المدني المجتمع منظمات) (هرباسيوم غوسيبيوم) القطن بذور ومخلفات (الدخن) في تخمير دراسة أجريت .القياسية الإجراءات باستخدام الفوري للتكوين وتقييمها وسحقها الفرن في هضم قابلية تحديد تم كما .ساعات 3 فترات على المحدد (الميثان) الغاز إنتاج مع ساعة 24 لمدة المختبر ، للاستقلاب القابلة والطاقة ، السلسلة قصيرة الحرة الدهنية والأحماض ، التخمير وكفاءة ، الجافة المادة الصحة منظمة في أعلى جافةال المادة محتوى كان .القياسية الإجراءات باستخدام العضوية المواد وهضم الصحة منظمة في قيمة أعلى وهي ، ٪ 15.75 إلى 4.66 من الخام البروتين محتوى تراوح .(94.00) العالمية .٪22.95 و 5.93 بين الرماد محتوى تراوح بينما ٪ 31.28 إلى 10.56 من الخام الألياف تراوحت .العالمية الدراسة من ساعة 24 بعد المنتج الغاز إجمالي كان .٪28.98 إلى 7.99 من الأثير مستخلص محتوى تراوح ، الميثان إنتاج .(مل 43.33) السوداني الفول حبات تليها (مل 48.00) القمح فضلات في أعلى المختبرية ، (سكفا) الحرة الدهنية الأحماض قصيرة سلسلة ، (الحديد) التخمير كفاءة ، (دمد) الجافة المادة هضم ، ٪ 64.80 إلى 43.83 ، مل 23.00 إلى 17.33 بين تراوحت (أومد) العضوية المواد وهضم (مي) الأيض الطاقة تشكل أن ويمكن .التوالي على ٪ 71.16 إلى 58.86 و كغ/مغ 9.62 إلى 7.24 ، 1.08 إلى 0.72 ، 1.18 إلى 1.13 قابلية وقيم الخام ينات البروت من الملموس المستوى ذات الزراعية الثانوية والمنتجات المحاصيل مخلفات .الحيوانات علف نقص من الحرجة الفترات خلال المجترات لإطعام جيدة غذائية موارد الهضم

الكلمات المفتاحية: علف المجترات ، المحاصيل بقايا ، الثانوية المنتجات ، الزراعية ، التخمير في
المختبر ، التركيب الكيميائي

Introduction

Nigeria's livestock industry makes a significant economic contribution to the country by creating jobs, supplying high levels of animal food protein, and reducing poverty. It also plays a significant role in the nation's diet by providing a highly rich source of animal protein (Isah et al., 2013). In many tropical nations, crop residues and agricultural by-products make up the majority of ruminant animals' feeds. With the present increase in rangeland conversion to agricultural fields, crop residues constitute the primary source of feed in the Sahel (Herrmann et al., 2020). Agricultural farms produce vast amounts of crop residue, which, despite being fibrous, may be digested by ruminants with the help of microorganisms found in their rumens. Ruminants in tropical regions rely on cut grasses and agricultural by-products because pasture is less readily available during the dry season (Sarnklong et al., 2010). Livestock productivity is limited in dryland grazing systems because feed demand and supply change within and between years as a result of environmental variability (Gicheha and Edwards, 2014). Crop-livestock systems have a range of economic and biological connections that draw farmers to them. In Nigeria, livestock and crop farming play a significant role in both farmers' and non-farmers' lives. Between 50 and 80 percent of Nigerians are engaged in crop or livestock agriculture (Akinola et al., 2015). In order to close the feed deficiency gap, it would be possible to increase animal production by using feed resources such as crop residues, which are readily available and cheap and have been identified as a significant source of nutrients in tropical ruminant nutrition (Mugerwa et al., 2012). Rice straw, maize stover, sorghum stover, corn cobs, and millet stover are a few examples

of crop residues. These feeds are often rich in carbohydrates in the form of cellulose and hemicellulose (Van Kujik et al., 2015). They are often referred to as lignocellulosic as they are rich in cellulose which is bound with biopolymer lignin. Crop residues are harvested, stored and fed to livestock and they provide a sizeable contribution to the total available feed supply during the dry season. Most crop residues have low levels of anti-nutrients and are therefore, suitable for livestock feed. The residues from cereal crops are of low nutritive value and less consumable (Singh et al., 2011). The objectives of this study were therefore to determine the chemical composition and in vitro fermentation characteristics of crop residue and agricultural by-products sold at the Aduwawa cattle market in Benin City, Nigeria.

Materials and methods

Collection of crop residue and agricultural by-products

Crop residues and agricultural by-products were the sourced from Aduwawa cattle market, Benin City, Edo state, Nigeria. The crop residue collected was groundnut (*Arachis hypogaea*) haulms, and agricultural by-products were common bean (*Phaseolus vulgaris)* husk, pearl millet (*Pennisetum glaucum*) offal, cotton seed (*Gossypium herbaceum)* offal and wheat (*Triticum aestivum L*.) offal.

Processing and handling of the feed materials

The fresh crop residue and agricultural by-products collected were taken to the Department of Animal Science Laboratory, University of Benin for analysis. A known weight of crop residue and agricultural by-products was placed into various foil paper and weighed. Each sample was replicated three times and the samples were dried with Genlab mini oven (manufactured by Genlab Limited, United Kingdom) at the temperature of 70 ^{o}C till a constant weight was attained. They were then milled to uniform a powder using blender and stored in a dry air-tight container until needed for analysis.

Experimental design

In vitro study was carried out in a completely randomized design (CRD).

Chemical analysis

The Association of Official Analytical Chemists (AOAC, 2005) standard procedure was used to analyze samples for dry matter (DM), crude protein (CP), ash, and ether extract (EE) content. The cell wall components, acid detergent fibre (ADF), and neutral detergent fibre (NDF), were determined using the method of Van Soest et al. (1991). The difference between NDF and ADF was used to compute hemicellulose.

In vitro fermentation study

Buffer preparation

The buffer was made a day before rumen liquor was collected, and it was kept at a pH of 6.2 and a temperature of 39 ^{o}C. The modified in vitro fermentation procedure by Navarro-Villa et al. (2011) was adopted. The buffer used consisted of the following reagents:

$Na_2HPO_4.12H_2O$ (1.985g/L), KH_2PO_4 (1.302g/L), $MgCl_2.6H_2O$ (0.105g/L), $NaHCO_3$ (5.418g/L) and NaOH (0.100g/L)

Collection of rumen liquor for in vitro study

Rumen liquor was collected from live goats housed at the University of Benin Farm Project, Ugbowo Campus, Benin City. The collection was via a stomach tube. The liquor was collected early in the morning (at 7 am) into a pre-warmed flask prior to the feeding of the goats. The flask containing the rumen liquor was taken to the laboratory where it was strained through four layers of cheese cloth. The strained liquor was mixed with a buffer solution in a ratio of 1:2. This mixture was placed in a shaking water bath XMTD-8222 (manufactured by Jinghong Laboratory instrument co. Ltd, China) and gassed with CO_2 to maintain anaerobic condition at a temperature of 39 ^{o}C to keep the micro-organisms alive.

In vitro fermentation of samples

Incubation of sample

One hundred and twenty milliliters (120 mL) calibrated syringes containing inoculums (rumen liquor: buffer, 1:2) was used to carry out the *in vitro* fermentation study. Two hundred milligrammes (200 mg) of the milled feed samples were weighed into the nylon bag, sealed and incubated at 39 ^{o}C with 30 mL of inoculums. The bags were placed inside the syringes before the inoculums were introduced into the syringes. The syringes were fitted with silicon tubes and clipped before placing them in Genlab mini incubator (manufactured by Genlab Limited, United Kingdom) at 39 ^{o}C. The

syringes containing only inoculums served as the blank while the bags containing only the substrate served as the control. Incubation time was noted, and gas production was monitored at 3 h intervals for 24 h. The syringes' headspace was measured to determine the volume of gas produced. After 24 h of incubation, the final readings were taken and the syringes were put on ice to stop further gas production. Methane production was determined at the end of the incubation period.

Determination of methane and dry matter digestibility

Forty percent (40%) NaOH was prepared, and 4 mL was injected into the incubation syringes at the end of the 24 h incubation period. Carbon (IV) oxide was absorbed by NaOH leaving behind methane. For dry matter digestibility (DMD), the sealed bags containing the samples were removed from the syringes and washed under running tap water until they became clean. The bags were then dried in Genlab mini oven (manufactured by Genlab Limited, United Kingdom) at a temperature of 100 °C until a constant weight was attained. The dry matter digestibility was calculated as follows:

$$DMD\ (\%) = \frac{A-B}{A} \times \frac{100}{1}$$

Where, A = weight of the sample before incubation

B = weight of the sample after incubation

The Fermentation Efficiency (FE) and effect of methane reduction (CH_4 red %) were calculated using the following formulas;

$$\text{Fermentation Efficiency (FE)} = \frac{\text{Dry matter digestibility (g/kg)}}{\text{Total gas volume (mL/kg)}}$$

$$CH_4 \text{ red } \% = \frac{\text{Average } CH_4 \text{ of the control} - CH_4 \text{ of treated sample}}{\text{Average } CH_4 \text{ of the control}} \times \frac{100}{1}$$

Post in vitro parameters

The metabolisable energy (ME), short-chain fatty acids (SCFA) and organic matter digestibility (OMD) was estimated using the following equations;

ME= 2.20 + 0.136 GV +0.057 CP + 0.00029 CF (Menke and Steingass, 1988),

OMD= 14.88 + 0.88 GV + 0.45 CP + 0.651XA (Menke and Steingass, 1988),

SCFA = 0.0239 GV - 0.0601 (Getachew et al., 1999)

Where GV= Total gas volume

CP= Crude protein

CF= Crude fibre; XA= Ash

Statistical analysis

Data collected were analysed using the GLM procedure of SAS (2013) and the separation of means was done using the Duncan Multiple Range Test (DMRT).

Results and discussion

The chemical composition of the crop residues and agricultural by-products are presented in Table I. Wheat offal (WHO) had the highest dry matter content (94.50%) while groundnut haulms (GDH) had the lowest (83.50%). The dry matter content of WHO was significantly ($P < 0.05$) different from those of GDH (83.50%), bean husk (BNH) (84.17%), cottonseed offal (CSO) (86.83%) and millet offal (MIL) (88.33%). The DM content (%) of WHO agreed with the value (95.65%) reported by Jonathan (2015) but was higher than 88.65 and 89.88 reported by Adeniji (2021) and Lamidi and Ogunkunle (2015) respectively. However, there was no significant ($P > 0.05$) difference between BNH (84.17%) and GDH (83.50%) samples. The DM content (%) for GDH was higher than the value (72.88%) reported by Finangwai et al. (2018). The variation in dry matter value may be due to the fibre and moisture content of the feed.

Table I: Chemical composition of some crop residues and agricultural by-products obtained at Aduwawa cattle market

Parameter (%)	Crop residues and agricultural by-products					
	WHO	**MIL**	**BNH**	**CSO**	**GDH**	**SEM**
DM	94.500^{c}	88.330^{b}	84.166^{a}	86.833^{b}	83.500^{a}	0.494
CP	15.750^{a}	10.500^{bc}	14.000^{ab}	9.333^{c}	4.667^{d}	1.021
EE	10.970^{c}	8.873^{d}	7.990^{d}	28.980^{a}	13.566^{b}	0.383
CF	10.566^{e}	22.953^{c}	31.286^{a}	22.020^{d}	29.856^{b}	0.232
ASH	10.690^{b}	22.566^{a}	8.336^{d}	9.650^{c}	5.936^{e}	0.222
OM	89.310^{d}	77.433^{e}	91.663^{b}	90.350^{c}	94.063^{a}	0.222
ADF	13.867^{d}	45.023^{a}	36.293^{b}	26.293^{b}	33.973^{b}	1.329
NDF	41.627^{b}	63.233^{a}	44.273^{b}	32.700^{c}	43.220^{b}	1.163
HEMI	27.760^{a}	18.210^{b}	7.980^{c}	6.253^{d}	9.246^{c}	0.443
NFE	52.023^{a}	35.107^{c}	38.387^{c}	30.017^{d}	45.973^{b}	1.309

a, b, c, d, e means with differ superscripts along the same row are significantly different ($P<0.05$), DM = Dry matter content, CP = Crude protein, EE = Ether extract, CF = Crude fibre, OM = Organic matter, ADF = Acid detergent fibre, NDF = Neutral detergent fibre, HEMI = Hemicellulose, NFE = Nitrogen free extract, SEM = Standard error of mean. WHO = Wheat offal, MIL = Millet offal, BNH = Bean husk, CSO = Cottonseed offal, GDH = Groundnut haulms

The WHO had the highest crude protein (CP) content (15.75%) while GDH had the lowest (4.67%). The CP concentration of WHO samples was substantially greater ($P<0.05$) than that of MIL (10.50%), CSO (9.33%), and GDH (4.67%), but not statistically ($P>0.05$) different from that of BNH (14.00%). There was no discernible difference between the CP content of CSO (9.33%) and MIL (10.50%) ($P>0.05$). The crude protein (CP) content of GDH was less than the critical 7% and 8% CP recommended for ruminant animals by ARC (1980) and NRC (1996) respectively while those of WHO, MIL, BNH, CSO were above the recommended level. The highest crude protein content obtained by WHO, was similar to 16.92% reported by Boukary (1999), although higher than 12.38% and 11.43% reported by Lamidi and Ogunkunle (2015) and Alikwe et al. (2012) respectively, it was however within the range (11.48 - 16.00%) reported for wheat bran by Mosimanyana and Kiflewahid (2006). The crude protein content of GDH was lower than the value of 14.40% and 11.40% reported by Tekle and Gebru (2018) and Tolera (2008) respectively. The CP Content of MIL was higher than the 6.20% and 5.52% reported by Ajeigbe (2003) and Mosimanyana and Kiflewahid (2006) respectively. The variation in CP may be due to variety, maturity at harvest, soil fertility, soil type, processing, environmental factors and seasonal effect (Qingxiang, 2002). The CP content of CSO was similar to the 18.24% reported by Boukary (1999). The ether extract (EE) content was highest in CSO (28.98%) and lowest in BNH (7.99%). In comparison to WHO (10.97%), MIL (8.87%), BNH (7.99%), and GDH (13.57%), CSO's EE content differed considerably ($P<0.05$). There was no significant difference between MIL (8.87%) and BNH (7.99%) samples. The amount of ether extract (EE) found in this investigation was consistent with the >50 g/10 Kg feed recommended for ruminant feeding (McDonald et al., 1995). The rumen bacteria' activities are slowed down by excess fat in ruminant diets. When contrasted with other crop residues, the BNH had the lowest EE content. The EE content of BNH was higher than the value (2.12%) reported by Tona et al. (2015). Fanangwai et al. (2018) and Jonathan (2015) reported the EE content of GDH to be 2.47% and 8.73% respectively, which were not comparable to what was obtained in this study. Low EE content in diet could imply low energy content and thus need to be supplemented with other energy sources such as grasses, legumes or concentrates, when animals are reared under zero grazing (Bamikole et al., 2006).

The WHO (10.57%) and BNH (31.29%) had the lowest and greatest respective crude fibre (CF) contents. WHO (10.57%), BNH (31.29%), MIL (22.95%), CSO (22.02%), and GDH (29.86) had substantially varied CF contents from one

another (P<0.05). The MIL, BNH, CSO, and GDH all had crude fibre (CF) contents that were greater than 18%, classifying them roughage feeds. The CF content of WHO was comparable with the value (10.00%) reported by Alikwe et al. (2012). CF content is influenced by the age of the plant. Conversely, a plant's CF is inversely correlated with its CP (Bamikole et al., 2006).

The MIL (22.57%) recorded the highest ash content while GDH (5.95%) recorded the lowest. When compared to the ash contents of WHO (10.69%), BNH (8.33%), CSO (9.65%), and GDH (5.94%), the MIL ash concentration (22.57%) was substantially different (P<0.05). According to this investigation, the ash content of WHO was higher than the value (3.90%) published by Adeniji (2021) and lower than the value (11.92%) recorded by Istifanus (2009). The presence of sand and its debris will translate to high ash content. Additionally, the ash contents of the WHO (10.69%), BNH (8.33%), COS (9.65%), and GDH (5.94%) samples varied significantly (P< 0.05).

The maximum organic matter (OM) concentration was found in the GDH (94.06%), while the lowest was found in the MIL (77.43%). The aforementioned was significantly different (P<0.05) from the OM content of WHO (89.31%), MIL (77.43%), BNH (91.66%) and CSO (90.35) samples. The OM content of the WHO (89.31%), MIL (77.43%), BNH (91.66%), and CSO (90.35%) samples, however, differed significantly (P<0.05).

The MIL had the highest concentration of acid detergent fibre (45.02%) while WHO had the lowest concentration (13.87%). ADF content was highest in the MIL (45.02%), which differed substantially (P<0.05) from those of WHO (13.87%), BNH (36.29%), CSO (26.29%), and GDH (33.97%). According to Kellems and Church (1998), roughages classified as high quality have an ADF value of less than 40%, while those classified as poor quality have an ADF value of more than 40%. Similarly, legumes classified as superior quality have an ADF value of less than 31%, while those classified as inferior quality have an ADF value of more than 55% (Kazemi et al., 2012). The MIL had the highest ADF value which can be categorically classified as poor-quality roughage. Forage with high ADF value suggests that it is inferior in quality, has low digestibility and decreases animal growth when fed for a long period of time (Jonathan, 2015). High ADF concentration has been found to be associated with a decline in voluntary feed intake in ruminants due to a slow rate of digestion (Riaz et al., 2014). However, there was no significant difference among WHO (13.87%), BNH (36.29%), CSO (26.29%) and GDH (33.97%) ADF values.

The MIL (63.23%) and CSO (32.70%) had the highest and lowest respective neutral detergent fibre (NDF) contents. The NDF concentration of the MIL sample was significantly different from the WHO (41.63%), BNH (44.27%), CSO (32.70%), and GDH (43.22%) samples (P<0.05), although there was no significant difference between the WHO (41.63%), BNH (44.27%), and GDH (43.22%) samples (P>0.05). Animals' voluntary feed intake will be influenced by the presence of high NDF in both individual feeds and the overall diet (Kebede et al., 2014). Roughage feeds are classified as high quality, medium quality, or low quality according to how much NDF they contain. Roughage feeds with an NDF concentration of less than 45% are considered to be of the highest quality (Singh and Oosting, 1992). While WHO, BNH, CSO, and GDH can be categorised as good quality roughages, the NDF concentration of MIL in this study falls within the range for poor medium-grade roughages classified by Sisay (2006) (58.00 - 67.53%). The high NDF content of feed influences the dry matter intake of ruminant animals.

The hemicellulose content ranged from 6.25 - 27.76%. The WHO (27.76%) which recorded the highest hemicelluloses content was significantly different (P<0.05) from those of MIL (18.21%), BNH (7.98%), COS (6.25%) and GDH (9.25%). However, there was no significant (P>0.05) difference between BNH (7.98%) and GDH (9.25%) hemicelluloses content, but there was a significant difference (P<0.05) among MIL (18.21%), BNH (7.98%), CSO (6.25%) and GDH (9.25%) samples.

The nitrogen-free extract (NFE) content varied from 30.02% (in CSO) to 52.02% (in WHO). The NFE content of WHO was significantly

(P<0.05) different from those of MIL (35.11%), BNH (38.39%), CSO (30.02%) and GDH (45.97%) samples. There was no significant (P>0.05) difference recorded between MIL (35.11%) and BNH (38.39%), but there was a significant difference among MIL (35.11%), BNH (38.39%), CSO (30.02%) and GDH (45.97%) samples.

Table II displays the in vitro gas production of agricultural residue and by-products at various times of incubation. At 3 hours of incubation, the WHO (14.000 mL/200 mg DM) recorded the highest gas volume, which was noticeably (P<0.05) higher than the control (7.33 mL/200 mg DM), and the BNH (5.33 mL/200 mg DM) recorded the lowest gas volume. The gas volume (mL/200 mg DM) of WHO (14.00) was significantly (P<0.05) different from those of MIL (7.33), BNH (5.33), CSO (6.67), GDH (6.67) and control (7.33) samples, but there was no significant (P>0.05) difference among the gas volume (mL/200 mg DM) of MIL (7.33), BNH (5.33), CSO (6.67), GDH (6.67) and control (7.33) samples.

Table II: In vitro gas (mL/ 200 mg DM) production of some crop residues and agricultural byproducts at different incubation time

Crop residues and agricultural byproducts	Time (h)							
	3	**6**	**9**	**12**	**15**	**18**	**21**	**24**
WHO	14.00^{a}	26.00^{a}	34.00^{a}	40.66^{a}	42.66^{a}	44.66^{a}	47.33^{a}	48.00^{a}
MIL	7.33^{b}	13.33^{b}	18.66^{b}	22.00^{b}	24.00^{b}	28.00^{b}	31.33^{b}	32.66^{a}
BNH	5.33^{b}	14.66^{b}	22.00^{b}	26.66^{b}	29.33^{ab}	32.66^{ab}	36.00^{ab}	38.66^{a}
CSO	6.66b	14.66^{b}	20.00^{b}	24.66^{b}	26.66^{b}	29.33^{b}	31.33^{b}	34.66^{a}
GDH	6.66^{b}	15.33^{b}	22.66^{b}	30.00^{ab}	32.66^{ab}	36.66^{ab}	40.66^{ab}	43.33^{a}
CONTROL	7.33^{b}	15.33^{b}	22.66^{b}	28.00^{ab}	30.66^{ab}	36.00^{ab}	41.33^{ab}	42.66^{a}
SEM	1.47	2.19	2.69	3.27	3.48	3.53	3.78	4.01

Means on the same row with different superscripts (a, b) are significantly different (P < 0.05), WHO= Wheat bran, MIL= Millet offal, BNH= Bean husk, CSO= Cottonseed offal, GDH= Groundnut haulms, h=hour, SEM=Standard error of means,

After six hours of incubation, WHO had the largest gas volume (26.00 mL/200 mg DM), which was substantially (P<0.05) higher than the gas volume for the control (15.33 mL/200 mg DM), while MIL had the lowest gas volume (13.33 mL/200 mg DM). In comparison to MIL (13.33 mL/200 mg DM), BNH (14.67 mL/200 mg DM), CSO (14.67 mL/200 mg DM), GDH (15.33 mL/200 mg DM), and control (15.333 mL/ 200 mg DM) samples, the gas volume of WHO (26.00 mL/200 mg DM) was significantly (P<0.05) greater. The gas volumes (mL/200 mg DM) produced by the MIL (13.33), BNH (14.67), COS (14.67), GDH (15.33), and the control (15.33) samples did not differ significantly (P>0.05). At 9 hours of incubation, the largest gas volume was obtained in WHO (34.000 mL/200 mg DM), which was also substantially (P<0.05) larger than the control gas volume of 22.67 mL/200 mg DM. MIL had the lowest gas volume (18.67 mL/200 mg DM). WHO had a substantially higher gas volume (34.00 mL/200 mg DM) compared to MIL (22.00 mL/200 mg DM), BNH (22.00 mL/200 mg DM), COS (20.00 mL/200 mg DM), GDH (30.00 mL/200 mg DM), and control samples (22.67 mL/200 mg DM) (P<0.05). The volume of gas produced by MIL (18.67 mL/200 mg DM), BNH (22.00 mL/200 mg DM), CSO (20.00 mL/200 mg DM), GDH (30.00 mL/200 mg DM), and the control (22.67 mL/200 mg DM) did not differ significantly (P>0.05).

At 12 hours of incubation, the gas volume observed in WHO was the highest (40.67 mL/200 mg DM), whereas the gas volume recorded in MIL was the lowest (22.00 mL/200 mg DM). Compared to MIL (22.00 mL/200 mg DM), BNH (26.67 mL/200 mg DM), and CSO (24.67 mL/200 mg DM) samples, the gas volume of WHO (40.67 mL/200 mg DM) was considerably (P<0.05), but not significantly (P>0.05) greater than those of GDH (30.00

mL/200 mg DM) and control (28.00 mL/200 mg DM). The gas volume produced by MIL, BNH and CSO samples, however, did not significantly (P>0.05) differ and neither did the GDH (30.00 mL/200 mg DM) and the control (28.00 mL/200 mg DM) samples.

At 15 hours of incubation, the gas volume measured by the WHO was the largest (42.67 mL/200 mg DM), and the gas volume measured by the MIL was the lowest (24.00 mL/200 mg DM), with a significant (P<0.05) difference between the two. In comparison to MIL (24.00 mL/200 mg DM), CSO (26.67 mL/200 mg DM), and BNH (29.33 mL/200 mg DM), WHO's gas volume was substantially (P<0.05) greater. However, it was not significantly (P>0.05) larger than those of GDH (32.67 mL/200 mg DM), control (30.67 mL/200 mg). In comparison to BNH (29.33 mL/200 mg DM), GDH (32.67 mL/200 mg DM), and the control sample (30.67 mL/200 mg DM), MIL's gas production (24.00 mL/200 mg DM) did not differ (P>0.05) substantially. However, there was no significant (P>0.05) difference between gas production by MIL (24.00 mL/200 mg DM)) and CSO (26.67 mL/200 mg DM)) samples, and there was no significant (P>0.05) difference in gas production among BNH (29.33 mL/200 mg DM)), GDH (32.67 mL/200 mg DM)) and the control (30.67 mL/200 mg DM)) samples.

At 18 hours of incubation, the WHO measured the maximum gas volume (44.67 mL/200 mg DM), while MIL measured the lowest (28.00 mL/200 mg DM). Gas production by WHO (44.67 mL/200 mg DM) was not substantially (P > 0.05) greater than that of BNH (32.67 mL/200 mg DM), GDH (36.67 mL/200 mg DM), and the control (36.00 mL/200 mg DM) samples, but it was significantly (P<0.05) higher than that of MIL (28.00 mL/200 mg DM) and CSO (29.33 Ml/200 mg DM). Gas production by MIL (28.00 mL/200 mg DM) was not significantly (P> 0.05) different from those of BNH (32.67 mL/200 mg DM), GDH (36.67 mL/200 mg DM) and the control (36.00 mL/200 mg DM) samples.

At 21 hours of incubation, gas volume (47.33 mL/200 mg DM) recorded in WHO was significantly (P<0.05) different from that of MIL (31.33 mL/200 mg DM) and CSO (31.33 mL/200 mg DM) samples but not significantly (P>0.05) different from those of BNH (36.00 mL/200 mg DM), GDH (40.66 mL/200 mg DM), or the control samples (41.33 mL/200 mg DM). Gas production by MIL (31.33 mL/200 mg DM) was not significantly (P>0.05) different from those of BNH (36.00 mL/200 mg DM), GDH (40.66 mL/200 mg DM) and the control (41.33 mL/200 mg DM) samples. Although MIL and CSO produced the least amount of gas compared to BNH, GDH and the control samples, there was no statistically significant (P>0.05) difference amongst the samples.

The gas volume (in mL/200 mg DM) at 24 hours ranged from 32.66 (in MIL) to 48.00 (in WHO). No significant (P>0.05) difference was observed in the gas produced among treatments at 24 hours of incubation. The WHO and MIL had the highest and least gas volume respectively at 24 hours of incubation. This may be a result of the soluble carbohydrate energy fraction contained in WHO which was readily available to the rumen microbes. This agreed with the findings of Sommart et al. (2000) and Nitipot and Sommart (2003) who stated that energy feeds with lower NDF showed a higher potential for gas production. The lowest value of the potential extent of gas production, obtained in MIL could be the result of the carbohydrate fraction having a high proportion of lignified cell walls, with the resulting low fermentation, and thus low gas production. This agrees with the findings of Melaku et al. (2003) who found that fibrous constituents, especially lignin negatively influence in vitro gas production. There are many factors that may determine the quantity of gas produced during fermentation which include the nature and level of fibre, the presence of secondary metabolite, the potency of rumen liquor and WHO carbohydrate fermentation. This could be responsible for high gas production in the wheat offal residue due to its high crude protein content.

Post in vitro fermentation parameters of some crop residue and agricultural byproducts is presented in Table III**.** Methane production was highest in WHO (23.000 mL) and lowest in CSO (17.333 mL) and control (17.333 mL). However, no significant (P>0.05) difference was observed in gas production among crop residues, crop byproducts and control samples. The production of methane gas best describes palatability, digestibility, fermentation end

products and microbial synthesis of the substrate by the microbes in the in vitro system (Sommart et al., 2000).

Table III: Post in vitro fermentation parameters of some crop residues and byproducts fed to ruminant animals at Aduwawa cattle market

	Post in vitro fermentation parameters						
Treatments	**CH_4 (mL)**	**CH_4 %**	**DMD**	**FE**	**SCFA**	**ME**	**OMD**
WHO	23.000[a]	0.486[a]	64.800[ab]	1.356[ab]	1.087[a]	9.629[a]	71.167[a]
MIL	20.000[a]	0.617[a]	43.830[b]	1.341[ab]	0.721[a]	7.248[a]	63.045[ab]
BNH	22.667[a]	0.670[a]	49.970[ab]	1.364[ab]	0.864[a]	8.266[ab]	60.636[ab]
CSO	17.333[a]	0.511[a]	50.470[ab]	1.515[ab]	0.768[a]	7.453[ab]	58.867[b]
GDH	18.667[a]	0.444[a]	74.430a	1.678[a]	0.975[a]	8.368[ab]	58.977[ab]
CONTROL	17.333[a]	0.403[a]	50.600[ab]	1.188[b]	0.975[a]	9.201[a]	63.550[ab]
SEM	2.482	0.085	6.069	0.113	0.095	0.545	3.530

a,b means on the same column with different superscripts are significantly different (P <0.05).CH_{4mL} = Methane, CH_4%= Methane percent, DMD = Dry matter digestibility, FE = Fermentation efficiency, SCFA = Short chain fatty acid, ME = Metabolisable energy, OM = Organic matter digestibility, SEM = Standard error of mean. WHO = Wheat bran, MIL = Millet offal, BNH = Bean husk, CSO = Cottonseed offal, GDH = Groundnut haulms

The highest methane production was recorded in BNH (0.6709 mL) and the lowest was recorded in control (0.4039 mL). Feedstuffs that have a high capacity for gas production indicate high methane production (Babayemi, 2007). Previous researchers (Babayemi and Bamikole, 2006; Silivong et al., 2013) reported that high methane production connotes a significant energy loss to ruminants, and this could contribute to global warming. However, the methane production by crop residues and the control sample were not significantly (P>0.05) different from each other.

The DMD (%) was highest in GDH (74.430) and lowest in MIL (43.830). The GDH value was not significantly (P>0.05) different from those of WHO (64.800), BNH (49.970), CSO (59.470) and the control (50.60) samples but was significantly (P<0.05) different from that of MIL (43.830). According to Owen and Jayasuriya (1989), crop residues with digestibility below 50% are said to be of poor quality. Only in vitro DMD of MIL and BNH falls below 50%; this connotes low digestibility. The nutritive value of feed influences its digestibility and therefore its intake. However, the % DMD of MIL was not significantly (P>0.05) different from those of WHO, BNH, CSO and control samples.

Fermentation efficiency (FE) was lowest in the control (1.188) sample and highest in GDH (1.678). The latter value was not significantly (P>0.05) different from those of WHO (1.356), MIL (1.341), BNH (1.3643) and CSO (1.515) and the control sample (1.188) which were not significantly (P>0.05) different from one another.

Short-chain fatty acid (SCFA) content ranged from 0.721 (in MIL) to 1.087 (in WHO). In vitro gas production method has been widely used to evaluate the energy value (Getachew et al., 2002) and short-chain fatty acid (SCFA) (Blummel et al., 1990) of several feeds. The SCFA values obtained for the various crop residues were within the range (0.74 - 1.22) for some forages reported by Yusuf et al. (2013). The presence of short-chain fatty acids or volatile fatty acids (VFA) such as acetate and butyrate suggests a potential to make energy available to ruminants (Yusuf et al., 2013).

Metabolisable energy (ME) was highest in WHO (9.629) which was not significantly (P>0.05) different from those of BNH (8.266), COS (7.453), GDH (8.368) and control (9.201) samples, but was significantly (P<0.05) different from that of MIL (7.248). The ME of MIL was not significantly (P>0.05) different from those of BNH (8.266), CSO (7.453), GDH (8.368) and the control (9.201) sample. However, there was no significant (P>0.05) difference among the ME of WHO, BNH, CSO, GDH and the control samples.

The organic matter digestibility (OMD) was highest in WHO (71.167) and lowest in CSO (55.867). The OMD of WHO was not significantly (P>0.05) different from those of MIL (63.045), BNH (60.636), GDH (58.977) and the control (63.550), but was significantly (P<0.05) different from that of CSO (55.867)

sample. The OMD of CSO was not significantly (P>0.05) different from those of MIL (63.045), BNH (60.636), GDH (58.977) and the control (63.550) samples. However, there was no significant (P>0.05) difference in OMD among MIL, BNH, GDH and control samples.

Conclusion

The study showed that wheat offal, groundnut haulms, and bean husk were of better nutritional value when fed to ruminants. Although wheat offal is essentially fibre, it is endowed with an appreciable amount of metabolisable energy which has made some contributions to the diet of ruminants. The study revealed that wheat offal, groundnut haulms and bean husk could be fed to ruminant animals with other feedstuff. The highest value obtained for the DMD in GDH implies higher nutrient availability for the rumen microbes. The study indicated that groundnut haulms can be incorporated into the diets of ruminant animals fed wheat offal while MIL is the lowest.

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