Converting Feed Waste to Wealth: Evaluation of Cabbage Waste Usage as Supplementation to Binary Mixtures of Crop Residues in Ruminant Nutrition

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Abstract
In this study, cabbage waste (CW) in combination with wheat offal (WO) and cassava peel (CP) was evaluated as ruminant feed resource, through the *in vitro* gas production technique. Five feed samples were formulated - T_1: 0% CW+70% WO+30% CP, T_2: 10% CW+60% WO+30% CP, T_3: 20% CW+ 50% WO+30% CP, T_4: 30% CW+40% WO+30% CP and T_5: 40% CW+30% WO+30% CP. Rumen liquor was collected from Yankassa rams (n=5) using the stomach tube and incubated at 39±1^{0}C using standard procedures. Data on proximate composition and *in vitro* gas production were determined using standard procedures, and were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. Dry matter values were not significantly affected by CW inclusion. The crude protein observed in T_1 (14.77±0.25) and T_2 (14.69±0.46) were significantly higher compared to other treatments. Lower crude fibre were observed in T_1 (19.67±0.49) and T_2 (19.76±0.64). However, T_2 (6.57±0.17) had the lowest ash content. Metabolizable energy ranged from 7.02±0.26 to 7.72±0.86 MJ/kg. Organic matter digestibility and short chain fatty acids concentrations were not significantly affected by varying levels of CW. Hence, cabbage waste supplementation did not compromise rumen integrity and ruminant farmers can harness its potentials during scarcity of green forages.

Keywords: cassava waste, chemical analysis, *In vitro* gas production, rams, ruminant nutrition.

1. Introduction

Ruminants play a vital role in the global agricultural industry, contributing significantly to the production of meat, milk, and other valuable products. However, ruminant feeding typically involves a substantial portion of crop residues and agricultural by-products, leading to inefficiencies and environmental concerns due to waste generation. Enhancement of ruminant production through the utilization of high-quality feed resources has been hampered by prevalent long dry season in the tropics, necessitating the adoption of nonconventional feed resources like vegetables and crop residues with relatively high nutritional properties.

The success of the livestock industry depends greatly on feed quality and quantity available for production purpose [1]. Inadequate nutrition mostly caused by attempts to cut excessively high cost and scarcity of feed remains major barriers that negatively influence livestock production. This therefore creates a gap between animal protein availability and required individuals' consumption in developing countries [2]. The use of unconventional feedstuff often reduces cost of production, as these are cheaper than conventional feedstuff and are readily available. The bulk of these

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residues and wastes if not handled through animal recycling, may become part of garbage and a concern for environmental pollution. In the tropics, the practice of using non- conventional feedstuff for animal feeding is very common and several researches have documented these [3 - 10]. However, it is very necessary to determine the nutrient composition of these feed resources in order to know whether they are suitable as livestock feed. Hence, there is a need to evaluate the utilization of vegetable residues from agro-processing plants in livestock rations. Some advantages of using vegetable residues like cabbage waste in animal feed include little competition as human food, good overall nutrient balance and ecological utilization of by-products [11]. The *in vitro* gas production system also aids the digestibility analysis and nutrient absorption and utilization process. It works by employing the rumen fermentation process. Thus, the capacity of a feed ingredient as a beneficial feed resource can be effectively evaluated [3]. However, information on the use of cabbage waste (CW) in combination with binary mixtures of cereal and tuber crop is scanty and thus needs to be investigated. This can provide useful information to farmers during scarcity of feed and during the peak production of cabbage, thereby helping to convert cabbage waste to wealth.

Since the objective of this study is to maximize the utilization of otherwise discarded agricultural by-products, reduce waste, and improve the overall efficiency of ruminant feeding systems, cabbage waste, a common by-product from vegetable markets and food processing industries, can enhance the nutritional quality of ruminant feed. This research evaluates the efficacy of cabbage waste supplementation when used solely or combined with binary mixtures of crop residues to enhance the nutritional value of ruminant feed. Hence, this study is therefore aimed at evaluating the usage of fresh cabbage waste, in combination with dried cassava peel and wheat offal as suitable feed resource through the *in vitro* gas production techniques.

2. Materials and methods

Experimental Site

The experiment was carried out at the sheep and goat unit of the Teaching and Research Farm, University of Ibadan, Oyo State, Nigeria, with latitude 7°26’ N and longitude 3°54’ E.

Experimental Layout

Five feed samples were formulated which are:

T1=0% Cabbage waste+70% wheat offal+ 30% Cassava peel
T2= 10% Cabbage waste +60% wheat offal+30% cassava peel
T3=20% Cabbage waste+50% wheat offal+30% cassava peel
T4=30% Cabbage waste+ 40% wheat offal+30% cassava peel
T5=40% Cabbage waste+ 30% wheat offal+ 30% cassava peel

Proximate Analysis, Fibre Fraction Determination and Incubation

Fresh cabbage waste, dried cassava peel, and wheat offal were purchased from a Salad Market, Cassava Processing Market and a feed mill respectively in Ibadan, Oyo state, Nigeria. Crop residues were analyzed for determination of proximate composition, fibre fraction and *In vitro* fermentation. Proximate analyses of the feed samples were also determined [12]. Nitrogen content was estimated by using standard Kjedahl procedure and crude protein content was determined, while the Acid Detergent Fibre (NDF), Neutral Detergent Fibre (NDF) and Acid Detergent Lignin (ADL) were determined using Van Soest method [13]. Prior to analysis, all samples were oven dried, grinded and milled using screen sieve milling machine. For the dry matter determination of each feed sample, an aluminum foil paper was weighed before putting 10g of each sample on it. These were placed in the oven to remove all moisture from the feed samples. A constant weight was determined and the samples were placed in desiccators to ensure minimum moisture re-absorption. In other to determine the organic matter content, 1g of each dried feed sample was transferred into the crucible which was placed into the muffle furnace at 600^0C for 16 hours. The final weight of the ashed sample was subtracted from the dry mater value to obtain the organic matter content of the feeds.

Rumen liquor from five (5) Yankassa rams was collected using the stomach tube. *In vitro* gas production was evaluated using the method of [14] to determine the amount of gas produced during a 24hour incubation period. The process of incubation was done at temperature of

39±1°C, after which the volume of produced gas was measured at 3rd, 6th, 9th, 12th, 15th, 18th, 21st, and 24th hour. After the process of incubation (24 hours), 5mL of NaO was introduced using 5mL capacity syringe. The post incubation parameters such as metabolizable energy, organic matter digestibility, methane, carbon IV oxide gases and short chain fatty acids produced were obtained at 24 hours after gas collection [14]. The average of the volume of gas produced from the blanks was deducted from the volume of gas produced per sample against the incubation time from the graph. A total of 30mL of the medium was pipette into 50mL plastic syringe and warmed to 39°C. The gas production was estimated using the equation:

$$Y = a+b\,(1 - e^{-ct})$$

where:
Y = volume of gas produced at time t,
a = intercept (gas produced from the insoluble fraction (b)
t = incubation time
e = apparently degraded substrate

Data Analysis
Data obtained were subjected to analysis of variance (ANOVA), using SAS software package [15] and means were separated using Duncan Multiple Range Test of the same package.

3. Results and discussion

Table 1 shows the proximate composition of dietary treatments. Dry matter content of dietary treatments ranged from 90.30 (T5) to 90.85 (T1). The crude protein (CP) observed in T1 (14.77) and T2 (14.69) were significantly (P<0.05) higher compared to T3 (13.59), T4 (13.48) and T5 (13.37). The Ether extract was not significantly (P>0.05) affected by varying levels of cabbage waste and values ranged from 2.61 (T5) to 2.75 (T2). Higher (P<0.05) Crude Fibre was observed in T3 (21.16), T4 (21.22) and T5 (21.34) compared to other treatments. The lowest (P<0.05) ash content was observed in T2 (6.57). Table 2 shows the fibre fractions of dietary treatments. The NDF, ADF, and NFE values were not significantly (P>0.05) affected by varying levels of cabbage waste in binary mixtures of wheat offal and cassava peel; and values ranged from 51.52 (T1) to 53.11 (T4), 39.15 (T5) to 41.22 (T4), and 55.50 (T5) to 56.56 (T1). The reports obtained from this study on nutritional composition of dietary treatments were consistent with the reports of [16] who noted that crude protein (CP) content of mixed feed-based diet had a range close to those from West African browse forages. Njidda and Ikhimioya [17] and [18] reported similar observations. However, [19] asserted that there are many factors affecting chemical composition and mineral content of forage feedstuffs, such as stage of growth, maturity, species or variety. These factors interact to confer an influence on the nutritive value obtained from agricultural wastes [20].

Table 1. Proximate composition of cabbage waste based mixed diet fed to the sheep (g/DM)

Parameters (%)	T1	T2	T3	T4	T5	SEM	P-value
DM	90.85±0.22	90.57±0.68	90.48±0.40	90.43±0.20	90.30±1.40	0.010	0.995
CP	14.77±0.25^{a}	14.69±0.46^{a}	13.59±0.37^{b}	13.48±0.5^{b}	13.37±0.35^{b}	0.080	0.002
EE	2.63±0.38	2.75±0.85	2.72±0.11	2.65±0.09	2.61±0.38	0.007	0.993
CF	19.67±0.49^{b}	19.76±0.64^{b}	21.16±0.10^{a}	21.22±0.32^{a}	21.34±1.04^{a}	0.097	0.011
Ash	6.36±0.24^{a}	6.57±0.17^{b}	6.78±0.44^{ab}	7.11±0.10^{a}	7.18±0.19^{a}	0.040	0.012

^{ab}Means along the row with different superscripts differed significantly (P<0.05) CP%= Crude protein content, EE%= Ether Extract, Ash%=Ash, DM%= Dry matter, T1=0% Cabbage waste+70% wheat offal+ 30% Cassava peel, T2= 10% Cabbage waste +60% wheat offal+30% cassava peel, T3=20% Cabbage waste+50% wheat offal+30% cassava peel, T4=30% Cabbage waste+ 40% wheat offal+30% cassava peel, T5=40% Cabbage waste+ 30% wheat offal+ 30% cassava peel

Table 2. Chemical composition of cabbage waste based mixed fed to sheep

Parameter (%)	T1	T2	T3	T4	T5	SEM	P-value
NDF	51.52±1.39	51.63±2.40	52.68±1.3	53.11±1.55	52.69±1.56	0.085	0.690
ADF	39.62±1.06	39.78±2.22	40.86±2.16	41.22±2.66	39.15±1.20	0.082	0.867
NFE	56.56±0.37	56.23±2.12	55.75±1.02	55.54±1.01	55.50±1.96	0.054	0.866

NDF= Nutrient detergent fiber, ADF= Acid Detergent fiber, NFE= Nitrogen free extract, T1=0% cabbage waste+70% wheat offal+ 30% cassava peel, T2= 10% cabbage waste +60% wheat offal+30% cassava peel, T3=20% cabbage waste+50% wheat offal+30% cassava peel, T4=30% cabbage waste+ 40% wheat offal+30% cassava peel, T5=40% cabbage waste+ 30% wheat offal+ 30% cassava peel

In vitro gas production of dietary treatments is shown in Table 3. It was observed that varying levels of cabbage waste did not significantly (P>0.05) affect fermentation of insoluble fractions, rate of gas production and net gas production; and values ranged from 37.21 (T5) to 42.11 (T3), 0.036 (T3) to 0.039 (T1) and 34.89 (T5) to 40.04 (T3), respectively. Blummel and Orskov [21] reported that the advantage of fermentation of insoluble fraction is for predicting feed intake and this value could account for 88% for variance intake. Groot *et al.* [22] also reported that carbohydrate fraction could be affected by kinetics of gas production. Intake of feed is mostly explained by the rate of gas production and this factor affects the rate of feed digestion through the rumen. Gas production is basically the result of fermentation of carbohydrate to volatile fatty acids [23].

The volume of gas and i*n vitro* gas production characteristics suggested that gas volume at 24hours after incubation is an indirect relationship with metabolizable energy in feed stuffs as reported by [20]. Gas production is an indicator of carbohydrate degradation [24]. However, gas volume is a good parameter to predict digestibility, fermentation, end product and microbial protein synthesis of the substrate. The rate of gas (C) production observed in this study was not significantly different in treatment groups. However, lower rate of gas production may indicate lesser availability of residues to microbes.

Table 3. *In vitro* characteristics of cabbage waste based mix fed to sheep

Treatments	A	B	c	a+b
T1	-1.91±0.39	39.36±5.96	0.039±0.004	37.45±5.58
T2	-2.15±0.24	39.10±4.24	0.037±0,006	36.95±4.07
T3	-2.07±0.05	42.11±6.35	0.036±0.005	40.04±6.35
T4	-1.97±0.28	40.65±3.89	0.038±0.007	38.68±2.39
T5	-2.33±0.12	37.21±1.94	0.038±0.001	34.89±1.91
SEM	0.14	2.74	0.003	2.69
P value	0.33860	0.7747	0.9752	0.7267

a=Intercept or initial gas production, b= potential degradability or fermentation of insoluble fraction, c = rates of gas production, a+b = net gas production, SEM = Standard error of mean, T1=0% Cabbage waste+70% wheat offal+ 30% Cassava peel, T2= 10% Cabbage waste +60% wheat offal+30% cassava peel, T3=20% Cabbage waste+50% wheat offal+30% cassava peel, T4=30% Cabbage waste+ 40% wheat offal+30% cassava peel, T5=40% Cabbage waste+ 30% wheat offal+ 30% cassava peel

Table 4 shows the metabolizable energy, organic matter digestibility and short chain fatty acid (SCFA) production of dietary treatments. It was observed that varying inclusion of cabbage waste did not significantly (P>0.05) affect metabolizable energy, organic matter digestibility and SCFA production in vitro, and values ranged from 7.02 to 7.38, 58.19 to 61.57 and 0.77 to 0.90, respectively. The results of this study on ME and organic matter digestibility were consistent with the reports of [11] who carried out a similar study on cauliflower, cabbage and pea and noted that the nutritive evaluation of some vegetable wastes, cabbage leaves, cauliflower leaves and pea pods have shown that they could serve as source of nutrients for ruminants. The results of this study for SCFA ranged from 0.77μmol to 0.90μmol and were consistent with the report of [20] who also confirmed that gas production from protein fermentation is relatively small compared to carbohydrate fermentation. Short chain fatty acid levels are directly proportional to metabolizable energy.

Table 4. Metabolizable energy, Organic matter digestibility and short chain fatty acid of dietary treatments

Parameters	T1	T2	T3	T4	T5	SEM	P value
ME (MJ/kg)	7.38±0.46	7.31±0.55	7.72±0.86	7.54±0.56	7.02±0.26	0.34	0.73
OMD (%)	58.96±4.96	58.61±3.61	61.01±5.64	61.57±3.68	58.19±1.70	1.76	0.80
SCFA (μmol)	0.84±0.13	0.82±0.10	0.90±0.15	0.87±0.10	0.77±0.05	0.21	0.77

ME = Metabolizable energy, SCFA= Short chain fatty acid, OMD = Organic matter digestibility, T1=0% Cabbage waste+70% wheat offal+ 30% Cassava peel, T2= 10% Cabbage waste +60% wheat offal+30% cassava peel, T3=20% Cabbage waste+50% wheat offal+30% cassava peel, T4=30% Cabbage waste+ 40% wheat offal+30% cassava peel T5=40% Cabbage waste+ 30% wheat offal+ 30% cassava peel

4. Conclusions

Organic matter digestibility and short chain fatty acids concentrations were not significantly affected by varying levels of CW. Cabbage waste supplementation did not compromise rumen integrity and ruminant farmers can harness its potentials during scarcity of green fodders, since cabbage waste have high nutrient potentials for ruminants, thereby helping to convert waste to wealth.

Conflict Of Interest

The authors declare no conflict of interest

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