NUTRITIONAL EVALUATION OF FRUITS AND VEGETABLE WASTE FOR LIVESTOCK FEEDING

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Abstract
This study evaluated the chemical composition, dry matter degradability, and *invitro* gas production of selected fruit and vegetable by-products to determine their suitability as ruminant feed. Dry matter content ranged from 80.07% to 94.50%, suggesting good shelf-life. Crude protein levels (5.15–16.65%) showed that many by-products met the minimum protein requirement for ruminant maintenance. Dry matter degradability varied significantly, with some by-products exceeding 50% after 48 hours, indicating high digestibility. *Invitro* gas production also varied, with orange peel producing the highest volume (70.10 mL at 48 h), followed by carrot tops and cabbage waste, demonstrating strong fermentability. Conversely, pawpaw and banana peels had the lowest gas volumes. Overall, orange peel, carrot tops, and cabbage waste show promise as alternative energy sources in ruminant diets, while less fermentable by-products may need to be part of mixed rations to enhance their utility.

Keywords: *Invitro* gas production, Fruit and vegetable waste, Nutrition, Fermentability, Ruminants

Description of the Problem

In semi-arid regions like northern Nigeria, livestock is vital for rural livelihoods, but its productivity is limited by seasonal feed shortages and the high cost of conventional feeds, especially during the dry season (1). To overcome these challenges, the use of fruit and vegetable waste (FVW) is gaining attention as a low-cost, nutrient-rich alternative feed source. However, due to their high perishability and short shelf-life, large quantities of fruits and vegetables are lost, leading to significant economic, social, and environmental waste (2). These by-products, which are often abundant and underutilized, are rich in energy, vitamins, and minerals, and can enhance livestock nutrition and productivity when included in rations (2). Nonetheless, proper evaluation of their nutritional composition and the presence of anti-nutritional factors like tannins and oxalates is crucial. To determine their digestibility and fermentation potential, *invitro* gas production techniques are employed, offering insights into their ruminal nutritional availability (3). The use of FVW not only supports improved livestock performance but also promotes environmental sustainability through food waste reduction. Therefore, this study aims to investigate the potential of FVW as a sustainable feed alternative in semi-arid Nigeria.

Materials and Methods

Experimental site

The experiment was carried out at the Livestock Teaching and Research Farm, Department of Animal Science, Faculty of Agriculture, University of Maiduguri, Borno State, Nigeria. Maiduguri is situated at latitude 11.015°N, longitude 30.05°E, and an altitude of 354 meters above sea level. The region lies within the semi-arid zone of West Africa, known for its brief rainy season and prolonged dry periods (4).

Sample preparation

Fresh samples were sourced locally within Maiduguri and properly sundried for a period of 7 days. All samples were ground to pass through 1 and 2 mm sieve and stored in polyethene bags for the study.

Chemical analysis

Samples were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), nitrogen free-extract (NFE) and ash, using the standard methods (5), while fibre fraction was determined according to the procedure of (6).

Rumen degradability study

Rumen degradability was evaluated using three rumen-cannulated bulls fed a basal diet of grass hay with a daily supplement of 2 kg of a concentrate mix (50% wheat bran, 40% cowpea husk, 10% cottonseed cake). Nylon bag technique was applied by incubating 5 g of each test feed in the rumen at different time intervals (3, 6, 12, 24, 48, 72, and 96 hours) as outlined by (7). The dry matter degradability (DMD) was calculated, and degradability data were fitted to the model $P = a + b (1 - e^{-ct})$ (8).

***Invitro* study**

An *invitro* gas production technique was employed following the method of (9). About 200 mg of feed sample was incubated in 100 ml glass syringes containing a buffered mineral solution and rumen fluid (mixed at a 1:2 ratio), maintained at 39 °C under CO_2 flushing. Gas production was recorded at 3, 6, 12, 24, and 48 hours. Blank syringes containing only buffered rumen fluid were also incubated. Metabolizable energy (ME) and organic matter digestibility (OMD) were estimated using the equations of (3), while short-chain fatty acids (SCFA) were determined based on the method of (10).

Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Statistix (10.0) in a Completely Randomized Design and means were separated using Least Significant Differences (LSD).

Results and Discussion

Chemical composition

The chemical composition of the fruit and vegetable by-products revealed significantly high dry matter (DM) content (80.07–94.50%), surpassing the typical range (11.9–23.3%) for fresh fruit and vegetable waste as reported by (11), indicating improved storage potential (12). Crude protein (CP) values ranged from 5.15 to 16.65%, aligning with earlier values reported for pineapple peels (13), and suggesting their suitability as protein supplements, given that ruminants require a CP level of 7–8% for maintenance.

Table 1: Chemical composition (%) of fruits and vegetable wastes

FEED	DM	CP	CF	EE	Ash	NFE
PAP	94.50^{a}	5.15^{e}	21.17^{c}	3.12^{de}	4.66^{d}	65.90^{a}
BP	86.72^{c}	7.77^{d}	17.02^{d}	7.93^{b}	10.05^{b}	57.23^{b}
WMP	94.00^{a}	11.11^{b}	27.66^{a}	9.82^{a}	4.92^{d}	46.49^{e}
OP	89.32^{b}	7.92^{d}	13.69^{f}	2.43^{e}	6.09^{c}	69.87^{a}
CT	94.90^{a}	9.00^{c}	15.70^{e}	3.80^{cd}	17.80^{a}	53.70^{bc}
CW	80.07^{d}	16.45^{a}	20.24^{c}	4.11^{c}	9.54^{b}	49.67^{de}
PPP	94.20^{a}	16.65^{a}	23.11^{b}	4.00^{c}	4.14^{d}	52.10^{cd}
SEM	0.392*	0.312*	0.311*	0.241*	0.275*	1.326*

Key: - DM = dry matter, CP = crude protein, CF = crude fibre, EE = ether extract, NFE = nitrogen-free extract, PAP= pineapple peels, BP = banana peels, WMP= watermelon peels, OP= orange peels, CT= carrot tops, CW= cabbage waste, PPP= pawpaw peels SEM = standard error of means, $^{a, b, c, d}$…. means in the same column bearing different superscripts are significantly ($p<0.05$) different, * = significant ($p<0.05$).

Dry matter degradability and characteristics of fruits and vegetable waste

The DMD data showed significant ($P<0.05$) differences among by-products, with increased DM disappearance over time. After 48 hours of incubation, some by-products (e.g., banana peels (BP), watermelon peels (WMP), orange peels (OP), and carrot tops (CT)) had DMD values exceeding 50%, indicating good digestibility (14). The soluble fraction (‘a’) was highest in BP (33.11%) and lowest in inner pineapple peels (IPP) at 8.36%, similar with earlier findings by (15). The insoluble but fermentable fraction (‘b’) was highest in OP (59.40%) and lowest in BP (9.42%), while the degradation rate constant (‘c’) ranged from 0.017/h to 0.079/h.

***Invitro* gas production, characteristics and estimated parameters of fruits and vegetable waste**

The *invitro* gas production, characteristics and estimated parameters (Table 3) showed significant differences ($P<0.05$) among the tested fruit and vegetable by-products. Gas production at 24 hours is indirectly related to the metabolizable energy (ME) of the feed, increasing due to microbial fermentation activity. Pineapple peels (PPP) had the lowest gas volume, likely due to high lignin content that delays microbial colonization. The insoluble but fermentable fraction 'b' varied from 55.59 ml in PPP to 103.3 ml in PAP, while OP recorded a higher 'b' value (72.38 ml) than previously reported (57.66 ml) by (16). As noted by (9), gas production kinetics are influenced by the proportion of soluble, degradable, and undegradable feed components. The fractional rate of gas production 'c' ranged from 0.014/h in PAP to 0.09/h in OP, with the rapid fermentation rate in OP likely due to its high soluble carbohydrate content. Organic matter digestibility (OMD) ranged from 38.34% in BP to 79.93% in OP, aligning with the range (54.10–76.12%) reported by (16). The higher OMD in OP, CT, and WMP may result from easily fermentable carbohydrates utilized by amylolytic microbes (17). Short-chain fatty acid levels ranged from 0.301 mmol in BP to 1.486 mmol in OP, exceeding the 1.12 mmol previously recorded for orange peels by (16), which reflects higher gas production and fermentation activity after 24 hours.

Table 2: Dry matter degradation and characteristics of fruits and vegetable by-products

	Fruits and vegetable waste							
Incubation hour	PAP	BP	WMP	OP	CT	CW	PPP	SEM
3	25.14b	36.00a	15.80d	21.80c	37.40a	16.17d	10.90e	2.123*
6	29.59d	42.05a	24.50e	32.70c	37.85b	20.70f	13.10g	2.085*
12	35.27cd	44.00b	33.95d	48.51a	49.00a	36.51c	19.40e	2.145*
24	41.59e	46.60c	44.18d	66.10a	53.00b	53.00b	23.00f	2.745*
48	52.20e	55.60d	50.60e	71.80a	64.50b	59.50c	44.90f	1.887*
72	57.76d	58.80d	53.57e	74.15a	70.10b	61.00c	46.00f	1.985*
96	62.95c	60.40d	55.40e	74.90b	86.50a	63.18c	56.00e	2.336*
Dry Matter Degradation Characteristics								
a%	23.50c	33.11a	12.25e	15.95d	32.10b	9.45f	8.89f	2.137*
b%	43.62e	29.42g	42.49f	59.40b	57.03c	53.81d	63.52a	2.475*
c^{-h}	0.023bc	0.028b	0.056a	0.064a	0.028b	0.057a	0.014c	0.004*
a+b%	67.12d	62.53e	54.74f	75.35b	89.13a	63.26e	72.41c	2.299*

Key: - a = soluble fraction, b = insoluble but degradable fraction, c = rate of degradation of b, a+b = potential degradability, SEM = standard error of means, $^{a, b, c, d}$…. means in the same column bearing different superscripts are significantly (p<0.05) different, * = significant (p<0.05).

Table 3: *Invitro* gas production, characteristics and estimated parameters of fruits and vegetable waste

	Fruits and Vegetable Waste							
Incubation Hours	PAP	BP	WMP	OP	CT	CW	PPP	SEM
3	3.50d	8.10c	10.00b	16.50a	10.20b	10.20b	4.20d	0.913*
6	6.70e	9.70d	23.80b	32.20a	24.50b	20.20c	6.90e	2.076*
12	9.85f	12.00e	31.40d	46.00a	37.40b	34.00c	10.50f	3.074*
24	29.00e	15.10f	42.90d	64.70a	53.30b	51.40c	15.00f	4.025*
48	51.50d	43.90f	49.00e	70.10a	58.60b	57.00c	39.50g	2.116*
***Invitro* gas production, characteristics and estimated parameters**								
b(ml)	103.30a	56.16cd	51.26d	72.38b	61.66c	59.91cd	55.59cd	3.79*
C(/h)	0.014g	0.022b	0.083a	0.090a	0.078a	0.071a	0.019b	0.007*
OMD (%)	46.01d	38.34e	61.22c	79.93a	77.90a	74.19b	38.20e	3.821*
SCFA (mmol)	0.633e	0.301f	0.965d	1.486a	1.214b	1.168c	0.298f	0.096 *
ME (MJ/kg DM)	6.50c	4.75e	8.75b	11.49a	10.01ab	10.19ab	5.23cd	0.571*

Key: b = insoluble but fermentable fraction, C = rate of gas production, OMD = organic matter digestibility, SCFA = short chain fatty acid, ME = metabolisable energy, SEM = standard error of means, $^{a, b, c, d}$…. means in the same row bearing different superscripts are significantly different (p<0.05),*= significant (p<0.05).

Conclusion and Application

The chemical composition and degradability of FVW reveal their potential as feed resources for ruminants. The *invitro* gas production effectively assessed their fermentability. Orange peel, carrot tops and cabbage waste showing the highest fermentation, making them suitable energy sources in ruminant nutrition. However, pineapple, banana, and pawpaw peels showed lower fermentability, suggesting they should be blended with more digestible feeds. These by-products can help reduce feeding costs and promote sustainable ruminant production.

References

1. Modu-Kagu H.A., Zarah, A.I., Abba-Aja, H.K., Abbator F.I. and Mohammed, I.D. (2021). Evaluation of Nutritive Value of Selected Browse Plants for Dry Season Supplementation in Semi-Arid Nigeria. *Nigerian Journal of Animal Science and Technology*, 4 (2): 28 – 42.
2. Tedesco, D.E.A., Scarioni, S., Tava, A., Panseri, S. and Zuorro, A. (2021). Fruit and Vegetable Wholesale Market Waste: Safety and Nutritional Characterisation for Their Potential Re-Use in Livestock Nutrition. *Sustainability*, 13, 9478. https://doi.org/10.3390/su13169478
3. Menke, K. H., and Steingass, H. (1988). Estimation of the energetic feed value obtained from chemical analysis and *invitro* gas production using rumen fluid. *Animal Research and Development*, 28: 7-55.
4. Raji, A. O., Buraimoh, M. A., and Gadzama, N. M. (2014). Agro-climatic characterization of Maiduguri region. *Journal of Environmental Sciences*, *8*(1), 45–52.
5. AOAC (2005). *Official Methods of Analysis of AOAC International*. 18th Edition. Gaithersburg, MD, USA.
6. Van Soest, P.J., Robertson, J.B. and Lewis, B.A. (1991). Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*: 3583-3597.
7. Ørskov, E.R., DeB. Hovell, F.D. and Mould, F.L. (1980). The use of the nylon bag technique for evaluation of feedstuffs. *Tropical Animal Production*, 5: 195-213.
8. Ørskov, E.R. and McDonald, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science.* (Cambridge). 92: 499-503.
9. Blummel, M., Makkar, H.P.S. and Becker, K. (1997). *Invitro* gas production: a technique revisited. *Journal of Animal Physiology and Animal Nutrition*, 77: 24-34.
10. Getachew, G., Blummel, M., Makkar, H.P.S. and Becker, K. (1997). *Invitro* gas measuring techniques for assessment of nutritional quality of feeds: a review. *Animal Feed Science and Technology*, 72: 261-281.
11. Negesse, T. (2009). Nutrient composition, volatile fatty acids production, digestible organic matter and anti-nutritional factors of some agro-industrial by-products of Ethiopia. *Ethiopian Journal of Science*, 32 (2): 149-156.
12. Okoruwa, M.I., Esobhawan, A.O. and Eghaghara, O.O. (2015). Mixture of orange and pineapple pulps meal as alternative energy sources in the diet of ram lambs. *Journal of Agriculture and Life Sciences*, 2 (1): 95-103.
13. Romelle, D.R., Ashwini, R.P, and Ragu S.M. (2016). Chemical composition of some selected fruit peels. *European Journal of Food Science and Technology*, 4 (4): 12-21.
14. Ehargava, P.K. and Ørskov, E.R. (1987). *Manual for the use of nylon bag technique in the evaluation of feedstuff*. Feed Evaluation and Experimentation Development Services. The Rowett Research Institute, Bucksburh, Aberdeen, Scotland, Pp. 1-20.
15. Bakshi, M.P.S. and Wadhwa, M. (2013). Nutritional evaluation of cannery and fruit wastes as livestock feed. *Indian journal of Animal sciences*, 83 (11): 1198-1202.
16. Akinfemi, A., Adesanya, A.O. and Aya, V.E. (2009). Use of an *invitro* gas production technique to evaluate some Nigerian feedstuffs. *American-Eurasian Journal of Scientific Research*, 4 (4): 240-245.
17. Kotarski, S.F., Waniska, R.D. and Thurn, K.K. (1992). Starch hydrolysis by the ruminant microflora. *Journal of Nutrition*, 122:178-190.