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IN VITRO GAS FERMENTATION KINETICS OF COMPOUNDED DIETS CONTAINING VARYING LEVELS OF *TETRAPLEURA TETRAPTERA* FRUIT MEAL

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Summary

The study investigated in vitro gas fermentation kinetics of compounded diets containing different quantities of *Tetrapleura tetraptera* (TTFM). Three replicates of each dietary sample (200 mg) were incubated in buffered rumen liquor for 48 hours and the parameters such as *in vitro* dry matter digestibility (IVDMD), organic matter digestibility (OMD), short-chain fatty acids (SCFA) and methane gas (CH4) were determined using in vitro gas production technique. One-way Analysis of Variance (ANOVA) was used to analyze the gathered data. The IVDMD exhibited substantial variation (p<0.05) among treatments. The diet with 1.0 % *Tetrapleura tetraptera* had the highest in vitro dry matter digestibility (IVDMD), which may be useful for effective feed conversion efficiency. The acetate and propionate with total volatile fatty acids raised the inclusion levels of TTFM in the rams' diet by 1.5 to 2.0 %. *Tetrapleura tetraptera* fruit meal can be added to ruminant diets at a rate of up to 2.0 % to increase daily weight gain, nitrogen utilization, and nutrient digestibility, resulting in better storage of energy.

Keywords: *in vitro,* digestibility, meal, diets, compounded.

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1. Introduction

Feed additives are non-nutritive substances or additives that are added to diets to increase dietary nutrient utilization, improve performance, reduce the risk of metabolic disorders, and reduce the negative environmental effects of diets [1].

Many research and production practices have been used, including the use of antibiotics, to attain the goal of higher net returns on quality meat [2]. Several antibiotics, including monensin, hainanmycin, and virginiamycin, have been used to increase ruminal fermentation and nutrient utilization efficiency [3, 4]. Despite their outstanding performance, antibiotics' possible side effects have become a major public health concern worldwide [5]. However, the widespread usage of these antibiotics has prompted concerns about product safety and environmental health. Natural plant species like *Ocimum gratissimum*, *Morinda lucida*, *Curcuma longa* and *Tetrapleura tetraptera* which are often inexpensive and environmentally safe can be introduced in ruminant feeding to mitigate methane production, promote growth and as anti-parasites to enhance animal health [6].

2. Materials and methods

The research was carried out at the Federal College of Animal Health and Production Technology's small ruminant unit, Moor Plantation in Ibadan. The unit is located in Nigeria's southwest region. The location is located in the rain forest ecological zone at longitude and latitude 7°–27° N and 3°–25° E, with an altitude of 220−300 m above sea level. The average rainfall is about 1250 mm. The temperature and relative humidity range from 30 to 35 °C and 76 to 84 %, respectively.

The fresh *Tetrapleura tetraptera* fruits were obtained at a reputed market in Ibadan, Oyo State, Nigeria. This was identified and verified at the Forest Research Institute of Nigeria (FRIN) Herbarium in Ibadan, Oyo State, Nigeria. The authenticated fruits were rinsed in sterile water and air-dried for two (2) consecutive weeks at room temperature before being milled into powdery form and compounding with other feedstuffs as fruit meal at 0 %, 0.5 %, 1.0 %, 1.5 %, and 2.0 % inclusion levels for treatments 1–5, respectively, as shown in **Table 1**.

Rumen fluid was collected from five rams early in the morning using suction tubes before being put into thermo-flasks pre-warmed to 39 °C. The samples were incubated according to [7] using 120 ml calibrated transparent plastic syringes with fitting silicon tubes (Rumen liquor: Buffer in ratio 1:2). Triplicate samples were carefully put into syringes, and 30 ml inoculums comprising cheese cloth filtered rumen liquid were added. The buffer (glitter) of $NaHCO_3 \cdot 2.77Na_2HPO_4 +$ $+0.57KCl+0.47NaCl+2.16M \cdot SO_7H \cdot 10 \cdot 16CaCl_2 \cdot 2H_2O$ was continuously flushed with CO_2 using another 60 ml plastic calibrated syringe. To eliminate air in the inoculums, the piston was used to tap the syringe and push it upward. To prevent gas from escaping, the silicon tubing in the syringe was tightened with a metal clip. The incubation period lasted 3, 6, 9, 12, 15, 18, 21, 24, and 48 hours. The headspace of the syringes was monitored and recorded during each incubation time. After 48 hours of incubation, the final measurements were collected, and the syringes were placed on ice to prevent additional gas formation. After incubation, 4 ml of NaOH (10M) was added to estimate methane generation, as stated by [8].

Determination of post-in vitro parameters (Dry Matter Digestibility (DMD), Short chain fatty acids (SCFA), Metabolizable Energy (ME), and Organic Matter Digestibility (OMD). The incubated samples were removed from the syringes, washed with water, and oven-dried at 100 °C to a constant weight, with the dry matter measured as a percentage of the original sample weight to compute dry matter digestibility (DMD):

DMD %=weight of the sample before incubation–weight of the sample after incubation×100.

The equation below was used to estimate the following post-incubation parameters: metabolizable energy, OMD, and SCFA [7, 9]:

$$ME=2.20+0.136GV+0.057CP+0.00029CF,$$

$$OMD=14.88+0.88GV+0.45CP+0.651XA\ ,$$

$$SCFA=0.0239GV–0.0601,$$

where *GV*, *CP*, *CF* and *XA* represent the total gas volume, crude protein, crude fiber, and ash of the incubated samples, respectively.

Table 1

Gross compositions of concentrate diets containing varying levels of *Tetrapleuratetraptera* fruit meal for WAD rams

Ingredients	Inclusion levels of TTFM (%)				
	0 %	**0.5 %**	**1.0 %**	**1.5 %**	**2.0 %**
Corn bran	30.00	30.00	30.00	30.00	30.00
Palm kernel cake	25.00	25.00	25.00	25.00	25.00
Rice bran	20.00	20.00	20.00	20.00	20.00
Wheat offal	15.00	15.00	15.00	15.00	15.00
Groundnut cake	5.00	5.00	5.00	5.00	5.00
TTFM	–	+	++	+++	++++
Dicalcium phosphate	3.00	3.00	3.00	3.00	3.00
[±]Premix	1.00	1.00	1.00	1.00	1.00
Salt	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00

Note: TTFM – Tetrapleura tetraptera fruit meal; + – 0.5 kg TTFM; ++ – 1.00 kg TTFM; +++ – 1.50 kg TTFM; ++++ – 2.00 kg; [±] *– contains:*

– Vitamin A (I.U.) – 10,000.000;
– Vitamin D_2 (I.U.) – 2,000,000;
– Vitamin E (I.U) – 20,000;
– Vitamin K (mg) – 2,250;
– Riboflavin (mg) – 5000;
– Pyridoxine (mg) – 275;
– Biotin (mg) – 50;
– Pantothenic acid (mg) – 7500;
– Vitamin B_1 (mg) – 175;
– Vitamin B_{12} (mg) – 15.0;
– Niacin (mg) – 27,500;
– Folic acid (mg) – 7500;
– Choline Chloride (mg) – 400;
– Antioxidant (mg) – 125;
– Fe (g) – 20.0;
– Zn (g) – 50.0;
– Mn (g) – 80.0;
– Cu (g) – 5.0 g;
– I (g) – 12.0;
– Co (mg) – 200;
– Se (mg) – 200.

Diets used in experiments:
– treatment 1: –100 % concentrate diet (CD) as control;
– treatment 2: –100 % CD+0.5 kg *Tetrapleura tetraptera* fruit meal;
– treatment 3: –100 % CD+1.0 kg *Tetrapleura tetraptera* fruit meal;
– treatment 4: –100 % CD+1.5 kg *Tetrapleura tetraptera* fruit meal;
– treatment 5: –100 % CD+2.0 kg *Tetrapleuratetraptera* fruit meal.

Presented in **Table 2** shows the chemical composition of *Tetrapleura tetraptera* fruit meal. indicating the proximate compositions, phytochemicals, micro-minerals and macro-minerals com-

ponents of the fruit meal. The dry matter content of 86.50 % was recorded for TTFM. The crude protein, ether extract, ash and nitrogen free extract values recorded were 11.30, 14.34, 5.67 and 58.28 % respectively. Furthermore, the phytochemicals in the TTFM were 0.42 g/kg Tannins, 1.98 g/kg Alkaloids, 0.16 g/kg Phenol, 2.43 g/kg Flavonoid, 0.24 g/kg sterol, 1.96 g/hydrogen cyanide and 1.15 g/kg saponins. *Tetrapleura tetraptera* fruit meal also contained calcium, phosphorus and magnesium contents of 28.44 mg/100 g, 35.62 mg/100g and 82.63 mg/100 g respectively. The micronutrient analyzed for African porridge fruit meal in the present study were manganese (52.62 mg/kg), iron (17.98 mg/kg), copper (7.16 mg/kg) and Zinc (2.17 mg/kg).

Table 2

Chemical compositions of *Tetrapleura tetraptera* fruit meal

Parameters (%)	*Tetrapleura tetraptera*
Dry matter	86.50
Crude protein	11.30
Ether extract	14.34
Crude fibre	10.41
Ash	5.67
Nitrogen free extract	58.28
Neutral detergent fiber	38.79
Acid detergent fiber	30.42
Acid detergent lignin	3.67
Cellulose	26.75
Hemicelluloses	8.37
Phytochemicals (g/kg)	
Alkaloid	1.98
Phenol	0.16
Flavonoids	2.43
Saponin	1.15
Hydrogen cyanide	1.96
Tannin	0.42
Sterols	0.24
Macrominerals (g/kg)	
Calcium	2.09
Phosphorus	0.82
Magnesium	0.15
Potassium	3.87
Sodium	0.17
Microminerals (mg/kg)	
Manganese	52.62
Iron	17.98
Copper	7.16
Zinc	2.17

Table 3 shows the chemical compositions of experimental diets containing varying levels of *Tetrapleura tetraptera* fed to West African dwarf rams. The crude protein (CP) contents ranged from 15.20–15.43 %. The ether extract values were similar varied from 8.40–9.02 % with 2.0 % TTFM having the highest value and 0 % inclusion level recorded the lowest value. The ash content ranged from 10.75–11.02 % with 1.5 % TTFM having the highest value. There were no marked variations in nitrogen free extract (NFE) of the diets (48.39–49.51 %). The diet with a 0 % TTFM inclusion level produced the highest NFE value. The neutral detergent fiber, acid detergent, and acid detergent lignin values were from 48.64–60.38 %, 34.64–47.19 %, and 9.87–17.11 %, respectively, with the greatest values obtained in the diet containing 2.0 % TTFM. The hemicelluloses and cellulose contents ranged from 13.19–15.78 % and 24.31–30.08 % respectively. The diet with 2.0 % TTFM had the highest cellulose value, while 1.0 % TTFM had the lowest value. For phytochemicals evaluated, 2.0 % TTFM recorded the highest values

for tannin, flavonoid, saponins, phenol for diets having 2 % inclusion level of TTFM. Furthermore, the lowest values of Tannin and other phytochemicals were recorded in the control diet with 0 % TTFM. The saponin contents were 0.71, 0.73, 0.78, 0.84 and 0.95 % from 0 % to 2.0 % TTFM respectively. The flavonoid and alkaloid contents of the diet also ranged from 2.32–3.54 % and 1.87–2.23 % respectively. The sterol phytochemical levels in this study ranged from 0.76 to 1.45 %. There were increases in the values of minerals determined in this present study. Except for the control, manganese, iron, and zinc levels increased throughout treatments as the TTFM level increased. The calcium, phosphorus, sodium, manganese and iron values ranged from 0.84–2.31 %, 1.12–2.22 %, 0.24–0.54 %, 234.12–267.68 mg/kg and 184.60–205.54 mg/kg respectively.

Table 3

Chemical compositions of experimental diet containing varying levels of *Tetrapleura tetraptera* fruit meal

Parameters	Inclusion levels of TTFM (%)				
	0	0.5	1.0	1.5	2.0
Dry matter	1.50	81.40	81.10	80.90	81.55
Crude protein	15.20	15.28	15.34	15.38	15.43
Ether extract	8.40	8.70	8.95	8.96	9.02
Ash	110.90	10.95	10.75	11.02	10.93
Crude fiber	115.89	15.91	16.05	16.10	16.23
Nitrogen free extract	49.51	49.16	48.71	48.54	48.39
Neutral detergent fiber	48.64	52.62	54.69	58.19	60.38
Acid detergent fiber	34.64	36.84	38.93	43.64	47.19
Acid detergent lignin	9.87	11.64	14.62	16.32	17.11
Hemicelluloses	14.00	15.78	15.76	14.55	13.19
Cellulose	24.77	25.20	24.31	27.32	30.08
Tannin	0.32	0.38	0.45	0.56	0.74
Saponin	0.71	0.73	0.78	0.84	0.95
Flavonoid	2.32	2.44	2.67	2.82	3.54
Alkaloid	1.87	1.86	1.90	2.01	2.23
Hydrogen cyanide	0.12	0.15	0.22	0.25	0.26
Sterol	0.76	0.96	1.11	1.36	1.45
Macro-minerals (g/kg)					
Calcium	0.84	0.92	1.24	1.68	2.31
Phosphorus	1.12	1.32	1.65	1.97	2.22
Magnesium	2.47	2.54	2.95	3.54	4.01
Potassium	0.74	0.56	0.98	0.79	0.98
Sodium	0.24	0.28	0.28	0.31	0.34
Micro-minerals (mg/kg)					
Manganese	234.12	242.23	251.23	264.33	267.67
Iron	184.60	177.80	173.30	195.45	205.54
Copper	11.34	8.79	10.33	11.65	10.98
Zinc	55.32	44.76	45.65	51.21	48.87

2. 2. Statistical analysis and experimental design

The data obtained were subjected to analysis of variance using [10] in a Completely Randomized Design. One-way analysis of variance (ANOVA) was used to estimate the means and standard error, and the treatment means were compared using Duncan's new multiple range test in the package.

3. Result and Discussion

3. 1. Cumulative gas volume production and post incubation parameters of diets containing *Tetrapleura tetraptera* fruit meal

Tables 4, 5 demonstrate the cumulative gas volume generation and post-incubation parameters for the experimental diets with different doses of TTFM. The results show that there was no significant difference (P>0.05) in the volume of gas produced with time (b). The volume of gas var-

ied between 10.00 and 12.13 mg/200 mgDM. Diets containing 1.5 % TTFM has the highest value, whereas those with 2.0 % TTFM has the lowest gas volume. It is also discovered that the rate of gas generation (*c*) and the duration between incubation and gas production (Lag) did not change substantially across dietary treatments ($P>0.05$). However, the highest rate of gas (0.49 ml/hr) value for the rate of gas production c is observed with 0.5 % TTFM inclusion level of *Tetrapleura tetraptera*. The time lag ranged from 0.24 to 1.60 hours, with the highest value obtained with a diet containing 2 % TTFM and the lowest with a diet containing 0.5 % TTFM. There are no significant differences ($P>0.05$) in all parameters observed, except for the in vitro Dry Matter Digestibility (IVDMD) with values ranging from 40.42 to 57.02 % at 1.0 % TTFM, which are significantly altered ($p<0.05$) by the TTFM inclusion. In this investigation, metabolizable energy (4.47–4.73 MJ/kg) and organic matter digestibility (OMD) ranged from 44.95 % to 46.69 %, although no significant difference ($p>0.05$) is found. The highest short chain fatty acids (0.28 µ mol) is observed with diets 2 % TTFM while other treatments recorded similar values which ranged from 0.22 to 0.23 µ mol. The gas volume at 48 hours ranged from 10.00–12.00 mL/mgDM.

Table 4

Cumulative gas volume production of concentrate diets containing varying levels of *Tetrapleura tetraptera* fruit meal

Treatment	*b* (ml/200 mgDM)	*C* (ml/hr)	*Lag* (hr)
(0 % TTFM)	11.79	0.46	1.20
(0.5 %TTFM)	12.13	0.49	0.24
(1 % TTFM)	10.96	0.16	1.11
(1.5 %TTFM)	12.06	0.19	0.84
(2.0 %TTFM)	10.00	0.25	1.60
SEM	0.93	0.14	0.92
P-value	0.59	0.53	0.74

Note: b – volume of gas produced in time t; c – fractional rate of gas produced; Lag – time between incubation and gas produced; TTFM – Tetrapleura tetraptera fruit meal.

Table 5 shows the post incubation parameters of concentrate diets containing graded levels of TTFM.

Table 5

Post incubation parameters of concentrate diets containing varying levels of *Tetrapleura tetraptera* fruit meal

Parameters	Inclusion levels of *Tetrapleura tetraptera* (%)					–	
	0	0.5	1.0	1.5	2.0	SEM	*P*-value
CO_2	4.50	3.50	4.00	4.50	3.50	0.25	0.55
IVDMD (%)	40.42^{d}	42.82^{b}	57.02^{a}	41.85^{c}	41.85^{c}	1.60	0.04
ME (MJ/kg)	4.69	4.73	4.68	4.69	4.47	0.05	0.90
OMG %	46.55	46.69	46.24	46.54	44.95	0.31	0.23
SCFA (µmol)	0.22	0.23	0.22	0.22	0.28	0.07	0.45
GV48 (ml/mgDM)	11.70	12.00	11.67	11.67	10.00	0.35	0.19

Note: ^{abc} means different superscripts along the same row are significantly different. ME – metabolizable energy; OMD – organic matter digestibility; GV48 – gas volume at 48 hours; IVDMD – in vitro dry matter digestibility; CO_2 – carbon-dioxide; SCFA – short chain fatty acids.

3. 2. Methane gas production of concentrate diets containing *Tetrapleura tetraptera* fruit meal

Fig. 1 shows the methane gas generation of concentrate diets with varied amounts of *Tetrapleura tetraptera* fruit meal. The maximum methane (ml/200 mg DM) generation value is achieved with a 0.5 % TTFM addition. The amount of methane gas produced reduces gradually as the inclusion of *Tetrapleura tetraptera* rose from diet 3 with 1 % TTFM to diet 5 with 2 % TTFM, respectively.

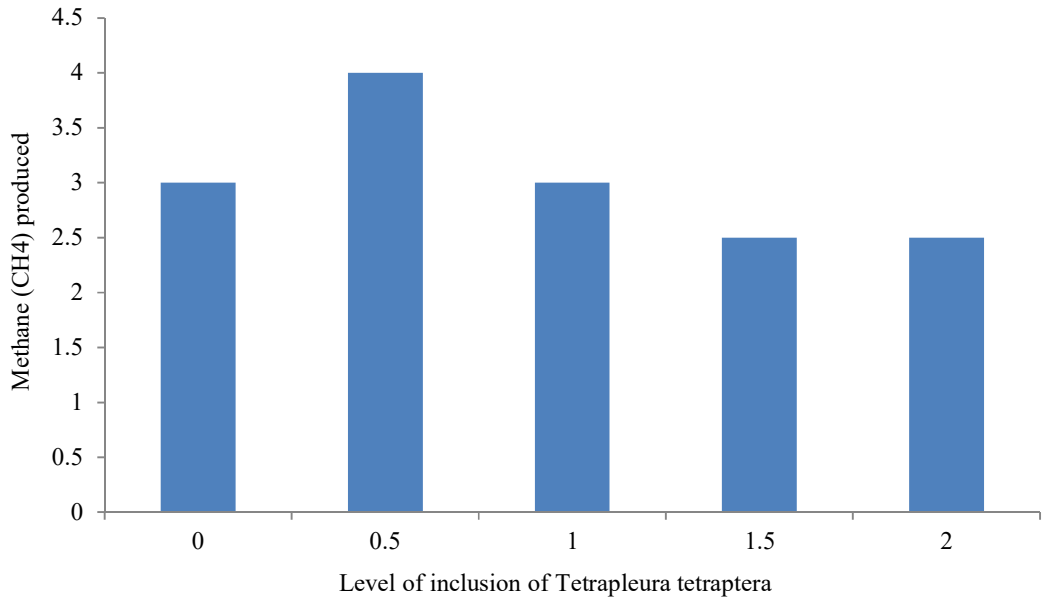


Fig. 1. Methane gas production of concentrate diets containing *Tetrapleura tetraptera* fruit meal

3. 3. Gas volume production of concentrate diets containing varying levels of *Tetrapleura tetraptera* fruit meal

Fig. 2 shows the gas volume production of concentrate diets with varied quantities of *Tetrapleura tetraptera* fruit meal after 3, 6, 9, 12, 15, 18, 24, and 48 hours. It is shown that the diet containing 0.5 % *Tetrapleura tetraptera* has the maximum gas volume production. It increases from 4 ml/hr to 10 ml/hr at steady rate. The lowest value for gas volume production is observed at diet containing 2 % inclusion level of *Tetrapleura tetraptera*fruit meal.

The chemical composition of *Tetrapleura tetraptera* analyzed in this current study reveals that the crude protein higher than the range 8.63–9.70 % reported by [11] and also within the range of 7.44–17.50 % reported by [12] for different varieties of *Tetrapleura tetraptera.* The ether extract level of TTFM measured in this investigation is also within the range (4.98–20.36 %) indicated by earlier findings of [13], who studied on the chemical ingredients of TTFM. The ether extract value found in this study is higher than the range (5.61–6.69 %) reported by [14] for the chemical contents and nutritional values of *Tetrapleura tetraptera* fruit. The crude fiber value observed in this investigation is consistent with the range of 11.38 to 12.30 reported by [15]. The mineral contents of TTFM discovered in this present study fell below the values 10.83, 24.14, 7.69 and 24.16 % for calcium, phosphorus, potassium and magnesium respectively reported by [11, 16]. The difference might be attributed to varieties of the plants and location of the experiment. The iron content of TTFM falls between the range of 15.1–19.3 % reported by [16] and 16.11–18.22 % reported by [14]. The present study found that *Tetrapeura tetraptera* fruit meal has more iron than other spices such as dried pepper, garlic, fig, and chestnut, with values (in mg/kg) of 12.0, 17.1, 15.3, and 10.1, respectively [17]. In agreement with previous studies, TTFM is an excellent supply of iron, which is a key component of hemoglobin and aids in the delivery of oxygen from the heart to all cells. The value obtained for iron level in this study more than 15 mg recommended by [18]. The proximate compositions of concentrate diets containing *Tetrapleura tetraptera* revealed in this study that crude protein is higher than the 8 % minimum protein requirement for optimal microbial functioning in the rumen [19] and within the 10–13 % recommended for ruminant growth and maintenance [20]. According to the findings, these high-crude protein diets can be utilized to replace poor-quality roughages in order to boost ruminant livestock production [21]. High crude protein levels in the experimental meal increased microbial proliferation in the rumen, which determined the degree of fermentation [22]. The concentrate diets in this current study have relatively high dry matter

as reflected in their values, this suggested that the diets may be stored for an extended amount of time without spoiling. According to [23], the environmental conditions in the rumen are typically favorable to fibrolytic microbes that aid in the decomposition of high crude fiber diets, as opposed to the deleterious effects of high carbohydrate concentrates. The ether extract value obtained for the diets in this investigation exceeds the range of 0.95–5.3 % stated by [24]. The ash content of the experimental diets produced in this investigation is consistent with the range of 11.20–12.80 % reported by [25] for diets compounded by replacing dry brewer grain with sorghum rootlets in feeding rams. This discovery, however, varies from the earlier report of [26], which shows ash contents of 7.00, 6.00, and 9.30 g/kg for fermented malted sorghum sprout. The values observed for nitrogen free extract in the diets are lower than the values (31.90–33.01 **%**) reported for agroindustrial Byproducts by [27]. There are also significant differences in nitrogen free extract (NFE) levels between the experimental diets, with 0 **%** inclusion of *Tetrapleura tetraptera* fruit meal having the highest NFE values recorded, indicating a high energy content in the diet.

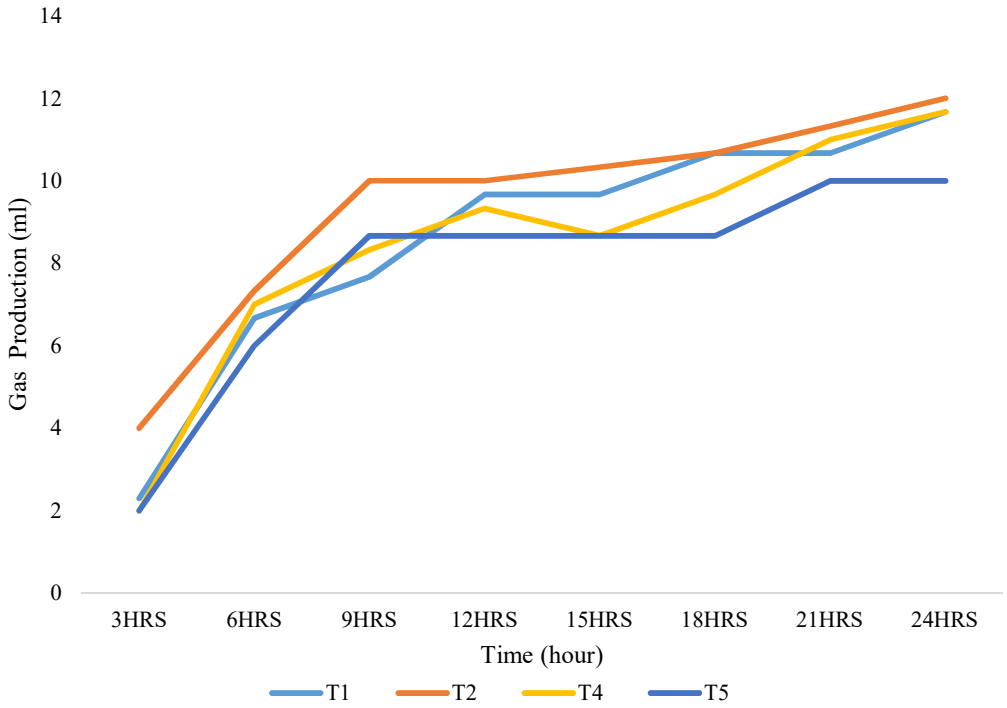


Fig. 2. Gas volume production of compounded ration containing graded level of *Tetrapleura tetraptera* fruit meal

The *in vitro* gas production technique estimates digestibility, fermentation rate of various feed fractions, and ruminal microbial synthesis [28]. Feed with inherent anti-nutritive factors has been reported to be low in metabolizable energy and organic matter digestibility [29] and metabolizable energy are useful indicator for determining the quantity of feed. The *in vitro* result in this current study reveals strong correlation between organic matter digestibility (OMD) and gas volume which corroborated with earlier findings by [30] who reported that an increase in gas volume leads to increased OMD when determining the *in vitro* fermentation characteristics of cassava, rice straw and dried ruzi grass as substrates. It also implies that the microorganisms in the animals' rumen have high nutrition uptake [31]. The short chain fatty acids (SCFA) estimated in this study is lower than the range (0.8–2.57 mol/L) reported by [8] when SCFA are determined using direct and indirect gas generation techniques. The SCFA value indicates that nutrients in the food will be readily utilized for maintenance and production after digestion [32]. Similar trends observed for OMD, SCFA and OMD in this current study indicate mutual relationship between ME, OMD

and SCFA as explained by [33]. The molar percentage of each SCFA produced is determined by the substrate used [34]. Gas volume represents the concentration of fermentable carbohydrates or carbohydrate breakdown, as well as nitrogen and lipids [35]. It also reflects the production of short-chain fatty acids and microbial mass [36]. An investigation performed by [37] revealed that the in vitro dry matter digestibility (IVDMD) approach, which simulates in vitro processes occurring in the rumen of cattle during plant digestion, is closely related to the decomposition processes of 12 plant materials with varying tissue quality. [38] described IVDMD as the best indicator for predicting feedstuff digestibility. The results for *in vitro* dry matter digestibility at 1.0 % TTFM show that the diet had higher percentage of decomposition compared with other treatments. According to [39], short chain fatty acids (acetic, butyric, and propionic acids) are created during rumen fermentation and can provide up to 80 % of the energy required for maintenance. [40] also described the significant connection between SCFA and gas output, which is utilized to estimate SCFA from gas volume, an indicator of animal energy availability. Thus, it can be concluded that increased short chain fatty acid (SCFA) generation in gas production technique is a trustworthy indicator of gas production and energy content of tested materials [41]. The methane value observed in this investigation is consistent with [42], which reported that methane gas production ranged from 2.5 to 4.0 (ml/200 mg DM) across dietary regimens. Several investigations have demonstrated the existence of bioactive substances such as phenolic compounds, condensed tannins, and saponins in *Tetrapleura tetraptera f*ruit meal [43]. These compounds have been shown to exhibit a variety of antibacterial characteristics [44]. These antimicrobial actions may modify the rumen microbial community, leading in lower methane emissions from TTFM-containing therapies [45]. Several investigations have shown that saponins or saponin-rich plants inhibit methane generation [46, 47]. Saponins may inhibit the action of methane-producing genes or their production in methanogenic cells, lowering methane generation [48, 49]. Saponins, on the other hand, may limit methane production by eradicating protozoans. Saponins' ability to link to sterols is the most likely cause of protozoan cell membrane breakdown [45]. In most cases, feedstuffs with a high gas production capacity are also found to produce a lot of methane. Methane generation implies energy loss for ruminants, and certain tropical feedstuffs have been linked to increased methanogenesis [50] as a component of carbohydrate metabolism. Reducing methane output improves feed utilization efficiency.

4. Conclusions

The diet containing 1.0 % *Tetrapleura tetraptera* had the highest in vitro dry matter digestibility (IVDMD), which could be useful for effective feed conversion efficiency. The acetate and propionate with total volatile fatty acids raised the TTFM inclusion levels in rams' diets by 1.5 to 2.0 %. *Tetrapleura tetraptera* fruit meal can be added to ruminant diets at up to 2.0 % to improve daily weight gain, nitrogen utilization, and nutrient digestibility based on available energy precursors.

Conflict of interest

The authors certify that they have no conflict of interest in respect to this research, whether financial, personal, authorship, or otherwise, that could influence the research and the results provided in this publication.

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Data availability

This manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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