Effect of fibre and digestible energy levels on growth performance, apparent nutrient digestibility and caecal fermentation of growing rabbits

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Abstract

A seventy-day feeding trial was conducted to investigate the effect of dietary fibre and digestible energy (DE) level on growth performance, apparent nutrient digestibility and caecal fermentation of growing rabbits. The experiment was laid out in a 3×3 factorial arrangement of 3 levels of fibre (low (249 – 258 g/kg NDF, 149 – 157 g/kg ADF), optimum (349 – 381 g/kg NDF, 188 – 193 g/kg ADF) and high (430 – 456 g/kg NDF, 249 – 253 g/kg ADF)) and 3 levels of DE (low (8 – 8.5 MJ/kg), optimum (10.5 – 11 MJ/kg) and high (12 – 12.30 MJ/kg)). A total of one hundred and thirty five weaner rabbits were allotted to 9 dietary groups of 15 rabbits each. Main effect of fibre showed that the final live weight and weight gain of rabbits increased ($P < 0.01$) while Ca retention reduced ($P < 0.001$) with increasing dietary fibre level. Rabbits fed (249 – 258 g/kg NDF, 149 – 157 g/kg ADF), had the worst ($P < 0.05$) feed to gain ratio. Rabbits fed (349 – 381 g/kg NDF, 188 – 193 g/kg ADF) had the highest apparent dry matter ($P < 0.05$), ether extract ($P < 0.05$), NDF ($P < 0.001$), ADF ($P < 0.001$) and organic matter digestibility ($P < 0.001$). Main effect of DE showed that rabbits fed high DE recorded the highest ($P < 0.05$) weight gain. Highest ($P < 0.01$) apparent dry matter, crude protein, ash, NDF, ADF, organic matter digestibility and Ca retention were recorded with rabbits fed optimum DE diet. Rabbits (445.70g/kgNDF, 252.10g/kgADF and 8.01MJ/Kg) recorded the highest ($P < 0.001$) final live weight, weight gain and feed intake ($P < 0.05$) while rabbits fed (249 g/kg NDF, 149 g/kg ADF and 8.17MJ/Kg) had the least ($P < 0.001$) final live weight, weight gain, apparent dry matter digestibility, NDF and ADF digestibility. Highest ($P < 0.001$) NDF digestibility was obtained with rabbits fed (370.79 g/kg NDF, 189.61 g/kg ADF and 10.84MJ/kg). Notwithstanding the DE level of the diets, rabbits fed with (430 – 456 g/kg NDF, 249 – 253 g/kg ADF) recorded the highest ($P < 0.05$) total VFA and acetic acid concentration. Rabbits fed (445.7g/KgNDF, 250.09g/KgADF and 10.52MJ/kg) recorded the best growth performance, improved caecal fermentation with no adverse effect on apparent nutrient digestibility.

Keywords: Growing rabbits; Dietary fibre; Digestible energy; Caecal fermentation

Introduction

The digestive physiology of rabbits is well adapted to high intake of plant cell wall. Fibre is regarded as one of the main constituent of rabbit feed ranging from 150

g/kg to 500 g/kg (Gidenne, 2003). A dietary fibre level of 335 – 400 g/kg NDF (De blas and Mateus, 1998; Garcia *et al.*, 1999), 170 g/kg ADF (De blas and Mateus, 1998) and a daily intake of 6 g lignin (Dalle Zotte, 2002)

were recommended for growing rabbits from previous findings. To formulate a ration that will meet these fibre levels, dietary energy concentration is mostly compromised. This is because diets which are highly fibrous are mostly characterized with low energy concentration (Gidenne *et al.*, 2000). High intake of highly fibrous feeds in rabbit nutrition has been reported to cause reduced feed efficiency (Gidenne *et al.*, 2000) and poor nutrient digestibility (Nicodemus *et al.*, 1999). However, attempts to increase the dietary energy concentration (in most cases at the expense of fibre) resulted in incidence of digestive disturbances (Lebas *et al.*, 1998), loss of appetite and reduced feed conversion efficiency (Bennegadia *et al.*, 2001). A research study aimed at striking an optimal balance between dietary fibre and energy levels is therefore necessary to encourage increased rabbit production especially in developing countries where meat protein from poultry and other livestock are not affordable by the larger populace.

Composition and levels of fibre in previous studies were reported to affect growth (Gutierrez *et al.*, 2002; Tao and Li, 2006), nutrient digestibility (Maitre *et al.*, 1990) and caecal fermentation of rabbits (Garcia *et al.*, 2002). The concentration of caecal volatile fatty acids (VFA) generated in rabbits has been used as a vital tool to estimate the efficiency of nutrient digestibility (Garcia *et al.*, 2000). Although few research have been conducted on the effect of fibre or energy on growth performance of rabbits (Fraga *et al.*, 1983; Maertens *et al.*, 1997; Tao and Li, 2006), studies investigating the combined interaction effect of fibre components (NDF, ADF and ADL) and digestible energy (DE) levels on growth, nutrient digestibility and caecal fermentation of growing rabbits is rare. This study therefore

seeks to investigate the effect of fibre and digestible energy on growth performance, nutrient digestibility and caecal fermentation of growing rabbits

Materials and methods

Experimental design and dietary treatments

The study was carried out at the rabbit unit of the Teaching and Research Farm of the University of Agriculture, Abeokuta, Nigeria. The rabbits were kept in a well ventilated building in which the maximum temperature was 30 °C and the minimum temperature was 27.6 °C. A cycle of 12 h of light and 12 h of darkness existed throughout the duration of the trial. Nine experimental diets having three levels of dietary fibre (low (249 – 258 g/kg NDF, 149 - 157 g/kg ADF), optimum (349 – 381 g/kg NDF, 188 - 193 g/kg ADF) and high (430 – 456 g/kg NDF, 249 - 253 g/kg ADF)), and in each case with three DE levels (low (8 – 8.5 MJ/kg), optimum (10.5 – 11 MJ/kg) and high (12 – 12.30 MJ/kg)) were formulated for a 3 × 3 factorial arrangements (Table 1). Dietary NDF (Pinheiro *et al.*, 2009) and ADF (Gidenne *et al.*, 2004) levels regarded as low fibre in this study were as reported in previous findings. Fibre components (NDF and ADF) considered as optimum in this study was as recommended by De blas and Mateous (1998) and Chao and Li (2008). Digestible energy levels of diets similar or close to the recommended value for maximum growth and meat production as reported in previous findings were considered as optimum (INRA, 1989; Lebas, 1991). The diets were offered to the animals in mash form.

Growth response and metabolic trial

A total of one hundred and thirty five, 5 weeks old, weaner rabbits, of mixed breeds with a mean body weight of 448.14 ± 16.05 g were randomly allotted into 9

dietary groups of 15 rabbits each. Rabbits were housed individually in cage units (each measuring 405 mm × 510 mm × 320 mm (LWH)) under an intensive housing system from the beginning to the end of the feeding trial which lasted 70 d. A total of 27 similar locally fabricated wired rabbit hutches (each of dimension 202.5 cm × 255 cm × 32 cm (LWH)) were used for the study with three hutches assigned to each treatment. Each hutch was partitioned into 5 equal cage units. The hutches were placed in well ventilated building. Feed intake and live weight were recorded per rabbit housed

in each cage unit (n=15 per treatment). The total feed intake, weight gain and the feed to gain ratio were also computed.

At the end of the feeding trial, five rabbits per treatment were randomly selected and housed in separate metabolic cages to measure apparent nutrient digestibility. The rabbits were acclimatized for 3 days prior to the commencement of the trial. Selected rabbits were fed with diet at quantity which matched their previous mean daily intake. Sample collection was done for four days. Excreta (free of feed particles and other contaminants) were collected daily from

Table 1 Gross composition of experimental diets (g/kg)

Fibre level	Low			Optimum			High		
Digestible energy level	Low	Optimum	High	Low	Optimum	High	Low	Optimum	High
Maize	225	190	130	235	195	135	204	164	124
Maize starch	90	110	145	90	115	140	80	100	120
Vegetable oil	5	20	45	5	20	55	10	30	50
wheat offal	230	230	230	140	140	140	60	60	60
Rice bran	90	90	90	130	130	130	195	195	195
Rice husk	60	60	60	100	100	100	151	151	151
Fixed ingredient including vitamin/mineral premix ^a	300	300	300	300	300	300	300	300	300
Determined composition (in g/kg)									
Dry matter	901.4	910.4	901.1	909.2	899.7	908.8	906.2	900.9	899.7
Organic matter	898.8	897.0	898.5	901.1	890.2	889.5	901.8	892.2	900.5
Crude ash	91.20	92.50	94.50	88.90	90.40	88.80	86.20	84.20	90.60
NDF	257.71	252.11	249.70	380.11	370.79	350.22	445.70	440.41	431.24
ADF	157.00	154.20	149.70	192.40	189.61	188.00	252.10	250.09	249.44
ADL	46.67	46.10	45.82	56.40	55.91	55.34	71.90	69.71	67.82
Gross energy (MJ/Kg)	12.03	16.09	17.62	12.67	16.95	19.13	14.19	18.56	21.29
Digestible energy ^b (MJ/Kg)	8.17	10.97	12.11	8.06	10.84	12.27	8.01	10.52	12.09
Ca	12.90	13.00	12.55	13.00	12.72	13.10	13.00	14.10	13.90
P	8.10	7.99	7.55	8.00	9.55	8.95	8.20	8.00	8.11

^a Contained : 250 g/kg soyabean meal (440 g/kg crude protein), 25.0 g/kg bone meal, 15.0 g/kg oyster shell, 2.0 g/kg lysine- HCL, 2.0 g/kg DL- methionine, 3.0 g/kg salt (NaCl) and 3.0 g/kg vitamin/mineral premix (providing the following per kg of diet 0.04g manganese, 0.034 g zinc, 0.023 g iron, 0.0026 g copper, 2.48 mg retinol, 0.003 mg cholecalciferol, 5.55 mg riboflavin, 0.70 mg thiamin, 0.70 mg pyridoxine, 2.80 mg niacin, 0.35mg calcium pantothenate and 0.70 mg cyanocobalamin

^b Calculated using de Blas *et al.*, (1992) (DE=GE × (0.867-0.0012ADF))

each cage and dried overnight (at 60 °C for 12 h). Feed samples and ground excreta samples (n=5 per treatment) were used for chemical analysis. Daily feed intake during the 4 d collection period was also measured. The total tract apparent nutrient digestibility (%) was estimated as:

$$= \frac{[(Fi \times Nf) - ((E \times Ne))] \times 100}{(Fi \times Nf)}$$

Where Fi and E is the quantity of feed intake and excreta output (g DM) during metabolic trial period. The Nf is the nutrient composition in feed while Ne is the nutrient composition in excreta voided (g DM).

Caecal fermentation

At the end of 70 d feeding trial, 5 rabbits were selected at random from each treatment (n=5 per treatment) and slaughtered. The caecal content of each rabbit was collected individually for the analysis of pH, NH₃-N and VFA. The pH of the caecal content was determined with a pH meter equipped with a probe. The caecal contents were centrifuged (25000 × g) at 0 °C for 10 min. The NH₃-N and VFA were further measured. For the measurement of NH₃-N concentration, twenty millilitres of supernate samples were poured into stopped glass flasks, mixed with about 20 ml of 0.2 M hydrochloric acid, stirred for 30 min. The NH₃-N concentration was determined spectrophotometrically using the technique of Weatherburn (1967).

For the determination of VFA concentration, a solution of 5% orthophosphoric acid (v/v) plus 1% mercury chloride (w/v) was added to the samples. Volatile fatty acids were measured by gas chromatography, with a gas column: free fatty acids and phenols 10% H₃PO₄, 1% acid-washed chromosorb W, 100 - 120 mesh. The carrier gas was N₂ with a flow rate of 40 ml/min: H₂ and air flows to the detector were 60 ml/min. Injector and detector temperatures were 250 °C while the

oven temperature was 150 °C.

Chemical analysis

Feed and dried excreta samples were analyzed for proximate constituents according to the Official Methods of Association of Analytical Chemists (A.O.A.C., 1990): ash (method No. 924.05), ether extract (method No. 920.39) and crude protein (total nitrogen × 6.25; method No. 984.13). For the determination of fibre fractions of feed and faecal samples, content of NDF was determined without sodium sulfite and with a heat-stable amylase (Van Soest *et al.*, 1991). Acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined by sequential analysis of the residual NDF and not expressed exclusive of residual ash (Van Soest *et al.*, 1991). The hemicellulose was calculated as the difference between NDF and ADF. The gross energy of the samples was determined using the ballistic bomb calorimeter. Minerals (which should be mentioned) were determined after wet-ashing by concentrated nitric acid and perchloric acid (1:1, v/v). Calcium, magnesium and phosphorus content were measured in the ash solution by atomic absorption spectroscopy (Techtron model AA-10) at 422.7, 285.2 and 430 nm, respectively (OJEC, 1973).

Statistical Analysis

Data obtained were laid out in a 3 × 3 factorial arrangement of treatments having three dietary fibre (low, (349 – 381 g/kg NDF, 188 - 193 g/kg ADF) and high) and three DE levels (low, optimum and high). Data obtained were analysed using SAS (2003) Software Package. Analysis was done to determine the main effects of fibre levels, digestible energy levels and combined interaction effect of dietary fibre and digestible energy levels. Differences between significant means were separated

using Duncans Multiple Range Test as outlined by Daniel (1991).

Results

Growth response and apparent nutrient digestibility

The main effect of dietary fibre and DE level on growth response and apparent nutrient digestibility of the rabbits is shown in Table 2. Final live weight and weight gain increased ($P < 0.01$) with increasing dietary fibre level. Rabbits fed with (430–456 g/kg NDF, 249–253 g/kg ADF) recorded the highest ($P < 0.05$) feed intake, final liveweight and weight gain. However, rabbits fed with (249–258 g/kg NDF, 149–157 g/kg ADF) had the worst ($P < 0.005$) feed to gain ratio. Highest apparent dry matter ($P < 0.05$), ether extract digestibility ($P < 0.05$), NDF ($P < 0.001$), ADF ($P < 0.001$) and organic matter digestibility ($P < 0.001$) were obtained with rabbits fed diet containing (349–381 g/kg NDF, 188–193 g/kg ADF). Ca retention reduced ($P < 0.001$) with increasing dietary fibre level. The least ($P < 0.001$) values of NDF, ADF digestibility, calcium and phosphorus retention were obtained with rabbits fed high fibre diets. Main effect of digestible energy level showed highest ($P < 0.05$) weight gain with rabbits fed with high DE levels. Rabbits fed with low DE recorded the least ($P < 0.001$) apparent dry matter, NDF, ADF, organic matter digestibility and Ca retention. Rabbit fed optimum digestible energy diets recorded the highest ($P < 0.001$) apparent dry matter, ash, ether extract, organic matter, NDF and ADF digestibility, nitrogen and Ca retention values.

Significant interaction of dietary fibre and DE levels existed for all parameters measured as shown in Table 3. Highest values of final live weight ($P < 0.001$), weight gain ($P < 0.001$) and feed intake ($P <$

0.05) were obtained with rabbits fed with diet containing (445.70g/KgNDF, 250.09g/KgADF and 10.52MJ/Kg). The worst ($P < 0.05$) feed to gain ratio were obtained with rabbits fed (257.71 g/kg NDF, 157.00 g/kg ADF and 8.17 MJ/kg) and those fed (252.21 g/kg NDF, 154.20 g/kg ADF and 10.97 MJ/kg). Rabbits fed diet containing (249.70g/kg NDF, 149.70g/kg ADF and 8.17MJ/Kg) had the least ($P < 0.001$) final live weight, weight gain, apparent dry matter, NDF and ADF digestibility. Highest ($P < 0.001$) NDF digestibility was obtained with rabbits fed diets containing (370.79g/kg NDF, 189.61g/kg ADF and 10.84 MJ/Kg) while highest ADF digestibility recorded with rabbits fed with (431.24 g/kg NDF, 249.44 g/kg ADF and 12.09 MJ/kg).

Cecal Fermentation

The main effect of dietary fibre and DE level on caecal fermentation of rabbits is as shown in Table 4. The concentration of total VFA and acetic acid increased ($P < 0.05$) with increasing dietary fibre level. The P^H level, concentration of NH_3 and propionic acid were not affected ($P > 0.05$) by the main effect of fibre level. Main effect of DE level showed no effect ($P > 0.05$) on the P^H level, concentration of NH_3 , acetic acid, propionic acid and butyric acid concentration. Rabbits fed with (8–8.5 MJ/kg) recorded the least ($P < 0.05$) total volatile fatty acid.

Significant interaction ($P < 0.05$) of dietary fibre and digestible energy level existed for the concentration of total VFA and acetic acid concentration produced (Table 5). Notwithstanding the DE level of the diets, rabbits fed with high fibre diets recorded the highest ($P < 0.05$) total VFA and acetic acid concentration.

Effect of fibre and digestible energy levels on growth performance of growing rabbits

Table 2: Main effect of dietary fibre and digestible energy levels on growth response and apparent nutrient digestibility of rabbits

Parameters	Main effect of fibre					Main effect of digestible energy				
	Low	Optimum	High	SEM	P value	Low	Optimum	High	SEM	P value
Final live weight (g/rabbit)	903.93 ^c	1087.13 ^b	1144.83 ^a	92.90	0.002	1053.90	1036.00	1046.00	94.80	0.076
Feed Intake (g/rabbit)	1716.67 ^b	1691.67 ^c	1749.90 ^a	104.55	0.035	1758.33 ^a	1661.00 ^c	1738.90 ^b	101.66	0.043
Weight gain (g/rabbit)	463.77 ^c	650.00 ^b	739.37 ^a	29.11	0.004	603.30 ^b	599.97 ^b	649.87 ^a	20.44	0.044
Feed to gain ratio	3.70 ^a	2.60 ^b	2.37 ^b	0.36	0.042	2.91	2.77	2.68	0.12	0.220
Apparent nutrient digestibility (%)										
Dry matter	76.9 ^b	78.50 ^a	74.35 ^c	6.12	0.044	70.23 ^c	81.23 ^a	78.32 ^b	8.71	<0.001
Ash	64.83 ^a	65.70 ^a	58.66 ^b	2.96	0.032	52.95 ^c	69.81 ^a	66.42 ^b	2.55	<0.001
Ether extract	91.43 ^b	94.30 ^a	92.14 ^b	2.98	0.025	89.32 ^b	94.51 ^a	66.42 ^c	3.45	<0.001
Nitrogen retention	81.26	81.12	80.21	1.22	0.950	78.88 ^c	82.73 ^a	80.98 ^b	1.10	<0.001
NDF	55.12 ^b	57.88 ^a	53.31 ^c	3.03	<0.001	48.96 ^c	60.36 ^a	56.99 ^b	2.99	<0.001
ADF	44.60 ^b	46.92 ^a	41.63 ^c	2.11	<0.001	34.82 ^c	51.51 ^a	46.81 ^b	2.10	<0.001
Organic matter	75.23 ^b	79.76 ^a	76.02 ^b	3.06	<0.001	71.99 ^c	96.80 ^a	79.52 ^b	2.97	<0.001
Calcium retention	69.00 ^a	68.33 ^b	65.67 ^c	2.98	<0.001	62.00 ^c	71.33 ^a	69.67 ^b	4.46	<0.001
Phosphorus retention	71.94 ^a	71.99 ^a	67.18 ^b	3.47	<0.001	69.02	70.97	70.91	3.39	0.950

^{a,b,c}Means on the same row with different superscripts are different significantly (P<0.05)

Table 3
Interactive effect of varying dietary fibre and digestible energy on performance characteristics and apparent nutrient digestibility of rabbits

Fibre level	Low			Optimum			High			SEM	P value
Digestible energy level	Low	Optimum	High	Low	Optimum	High	Low	Optimum	High		
Final weight (g/rabbit)	811.80 ^a	850.00 ^g	1050.00 ^e	1125.00 ^c	1070.70 ^z	1065.70 ^d	1224.90 ^a	1187.30 ^b	1022.30 ^f	90.24	<0.001
Feed Intake (g/rabbit)	1750.0 ^c	1700.00 ^c	1700.00 ^c	1650.00 ^f	1700.00 ^c	1725.00 ^d	1875.00 ^a	1583.00 ^g	1791.70 ^b	100.8	0.025
Weight gain (g/rabbit)	366.30 ^f	412.50 ^c	612.50 ^d	668.80 ^c	668.60 ^c	612.60 ^d	774.80 ^a	718.80 ^b	724.50 ^b	33.51	<0.001
Feed to gain ratio	4.78 ^a	4.12 ^a	2.78 ^b	2.47 ^b	2.54 ^b	2.82 ^b	2.42 ^b	2.20 ^b	2.47 ^b	0.83	0.042
<i>Apparent nutrient digestibility (%)</i>											
Dry matter	63.40 ^c	79.70 ^b	87.67 ^a	78.30 ^b	88.87 ^a	68.34 ^d	69.00 ^d	75.11 ^c	78.95 ^b	7.22	<0.001
Ash	44.38 ^c	68.67 ^b	81.43 ^a	65.23 ^c	81.94 ^a	49.94 ^d	49.23 ^d	38.82 ^f	67.90 ^b	4.55	<0.001
Ether extract	83.67 ^f	77.88 ^g	86.62 ^c	78.44 ^g	97.22 ^a	91.25 ^c	89.85 ^d	92.36 ^c	94.22 ^b	3.77	<0.001
Nitrogen retention	76.64 ^c	82.28 ^b	84.85 ^a	81.24 ^b	85.25 ^a	76.88 ^c	78.77 ^c	80.67 ^b	81.20 ^b	4.55	<0.001
NDF	40.85 ^c	57.88 ^b	46.62 ^d	58.78 ^b	68.08 ^a	46.57 ^d	47.04 ^d	55.11 ^d	59.77 ^b	6.01	<0.001
ADF	23.34 ^g	48.85 ^c	41.60 ^d	47.49 ^c	62.39 ^b	30.88 ^f	33.64 ^c	42.30 ^d	67.96 ^a	3.55	<0.001
Organic matter digestibility	65.44 ^c	63.81 ^c	88.33 ^a	79.67 ^b	89.48 ^a	70.13 ^d	70.87 ^d	77.10 ^c	80.09 ^b	4.02	<0.001
Calcium retention	63.00 ^d	70.00 ^b	74.00 ^a	67.00 ^c	74.00 ^a	64.00 ^d	56.00 ^c	70.00 ^b	71.00 ^b	4.99	<0.001
Phosphorus retention	68.89 ^c	71.22 ^b	75.10 ^a	74.38 ^a	75.46 ^a	66.12 ^d	63.79 ^d	66.24 ^d	71.51 ^b	3.94	<0.001

^{a,b,c,d,e,f,g} Means on the same row with different superscripts are different significantly (P<0.05)

Table 4: Main effect of varying dietary fibre and digestible energy on caecal fermentation of rabbits

Parameters	Main effect of fibre					Main effect of digestible energy				
	Low	Optimum	High	SEM	P value	Low	Optimum	High	SEM	P value
P ^H	6.270	6.47	6.63	0.41	0.105	6.43	6.43	6.50	0.39	0.091
NH ₃ N	2.87	2.67	2.50	0.29	0.075	2.73	2.63	2.67	0.19	0.210
Caecal VFA (mmol/100ml)										
Total	4.53 ^c	6.33 ^b	8.17 ^a	0.97	0.022	5.80 ^b	6.60 ^a	6.63 ^a	0.78	0.044
Acetic	2.96 ^c	4.50 ^b	5.70 ^a	0.95	0.034	3.97	4.67	4.50	0.32	0.110
Propionic	0.33	0.53	0.70	0.04	0.090	0.50	0.57	0.53	0.02	0.902
Butyric	0.73	0.96	1.13	0.01	0.092	0.83	1.07	0.93	0.04	0.140

^{a,b,c} Means on the same row with different superscripts are different significantly (P<0.05)

Discussion

Growth response and apparent nutrient digestibility

The highest weight gain and improved feed to gain ratio obtained with rabbits fed diet containing (445.70 g/kg NDF, 252.10 g/kg ADF and 8.01 MJ/Kg) agreed with previous findings that rabbits can be sustained on high fibre diets (De Blas *et al.*, 1995; Tao and Li, 2006). Improved growth response were also reported in literature with growing rabbits fed diets containing 233 g/kg ADF and 73 g/kg ADL (Pinheiro *et al.*, 2009). The result however contradicted the findings of Chao and Li (2008) who reported a deteriorating poorer feed to gain ratio when rabbits are fed with dietary ADF above 190 g/kg level. These differences could be attributed to differences in the nature of dietary ingredients and breeds of rabbits used

Highest feed intake noticed with rabbits fed (445.70 g/kg NDF, 252.10 g/kg ADF and 8.01 MJ/Kg) diet agreed with the fact that rabbits have the ability to adjust its voluntary intake in response to changes in dietary energy concentration (Macrtens *et al.*, 1988; Patridge *et al.*, 1989). Rabbits fed (430 – 456 g/kg NDF, 249 - 253 g/kg ADF) diets (characterized mostly with low energy concentration) tend to consume more feed to meet its energy requirement. Similarly, rabbits fed with (249.70 g/kg NDF, 149.70 g/kg ADF and 12.11 MJ/Kg) diet resulted in (249 – 258 g/kg NDF, 149 - 157 g/kg ADF) intake (Gidenne, 1997) which could lead to increased incidence of digestive disturbances, enteritis, diarrhea and poor feed conversion efficiency (Lebas *et al.*, 1998; Bennegadia *et al.*, 2001). Compromise in fibre intake has been reported to cause digestive disturbances in the gut of rabbits (De blas, 1992). Although, main effect of DE recorded high weight gain with rabbits offered high DE diets,

improved feed conversion ratio were obtained when diet containing combination of (445.70 g/kg NDF, 252.10 g/kg ADF and 8.01 MJ/Kg) is fed. This was in consistent with Nguyen and Nguyen (2008) who concluded that dietary inclusion of up to 410 g/kg NDF in rabbit nutrition gave higher growth rates and better benefits for rabbit producers.

Improved nutrient digestibility and mineral retention obtained with rabbits fed diet containing (370.79 g/kg NDF, 189.61 g/kg ADF and 10.84 MJ/Kg) could be due to the fact that dietary fibre (De blas and Mateus, 1998; Garcia *et al.*, 1999; Gidenne *et al.*, 2001) and DE levels (INRA, 1989; Lebas 1991) at this point lied within the recommended level as reported in previous studies. It could also be due to appropriate proportion of cellulose, lignin (low digestible fibre) and hemicellulose (high digestible fibre) which are considered to be adequate in rabbit nutrition (Gidenne and Perez, 2003). The nature (Gidenne *et al.*, 1987; Garcial *et al.*, 1999) and levels of dietary fibre (Gidenne, 2000) were reported to affect nutrient digestibility in rabbits. The degree of lignification (Gidenne and Perez, 1994) and ligocellulose ratio (Gidenne *et al.*, 2001) of the diet containing (370.79 g/kg NDF, 189.61 g/kg ADF and 10.84 MJ/Kg) diet were also adequate for growing rabbits as reported in previous literatures. This could be contributory to the improved nutrient digestibility obtained with rabbits fed diet containing (370.79 g/kg NDF, 189.61 g/kg ADF and 10.84 MJ/Kg). The solubility of the dietary fibre components also determines its nutrient digestibility. Inclusion of soluble fibre in pigs delay gastric emptying due to its ability to swell and forms a viscous material (Anderson, 1985), hence improved digestion (Davidson and Mc Donald, 1998) and increased microbial fermentation

Table 5: Interactive effect of varying dietary fibre and digestible energy on caecal fermentation of rabbits

Fibre level	Low			Optimum			High			SEM	P value
Digestible energy level	Low	Optimum	High	Low	Optimum	High	Low	Optimum	High		
pH	6.30	6.20	6.30	6.40	6.50	6.50	6.60	6.60	6.70	0.69	0.095
NH ₃ -N (mmol/100ml)	2.90	2.90	2.80	2.70	2.60	2.70	2.60	2.40	2.50	0.09	0.066
Caecal VFA (mmol/100ml)											
Total	4.20 ^d	4.60 ^c	4.80 ^c	5.00 ^c	6.80 ^b	7.20 ^b	8.20 ^a	8.40 ^a	7.90 ^a	0.77	0.122
Acetic	2.70 ^c	3.20 ^c	3.00 ^c	3.50 ^c	4.90 ^b	5.10 ^b	5.70 ^a	5.90 ^a	5.50 ^a	0.72	0.094
Propionic	0.30	0.40	0.40	0.50	0.50	0.60	0.70	0.80	0.60	0.09	0.059
Butyric	0.70	0.70	0.80	0.70	1.20	1.00	1.10	1.30	1.00	0.06	0.050

^{a,b,c,d} Means on the same row with different superscripts are different significantly (P<0.05)

(Jorgensen and Jensen, 1994).

Interestingly, the main effect of dietary fibre in this study showed low nutrient digestibility values with rabbits fed (430 – 456 g/kg NDF, 249 - 253 g/kg ADF) diets. Maitre *et al.* (1990) reported reduced nutrient digestibility when rabbits are fed with increasing level of NDF above the range of 248 - 323 g/kg. Literatures confirmed that dietary fraction most related to digestive disturbances in rabbits is insoluble neutral detergent fibre (De Blas *et al.*, 1999; García *et al.*, 2002). Nguyen and Nguyen (2008) also reported reduced dry matter and organic matter digestibility with increasing dietary level of NDF. Excessive intake of dietary fibre decreased gut retention time and increased caecotrophe production due to increasing fibrolytic activity (Perez *et al.*, 1996; Gidenne *et al.*, 1998). In such situation, excessive high intake of fibre could results in a reduction of nutrient digestibility (Deblas *et al.*, 1999).

Caecal fermentation

The concentration of VFA produced in this study agreed with the proportion of 60 - 80 mol of acetate, 8 - 20 mol of butyrate and 3 - 10 mol of propionate per 100 ml of VFA produced as reported by Gidenne (1996). Volatile fatty acids (VFAs) produced as a result of caecal fermentation of digestible fibre (Nicodemus *et al.*, 1999) or undigested nutrients (De blas and Gidenne, 1998) provide a vital source of energy for the rabbits (Bellier and Gidenne, 1996). Rabbits fed with (430 – 456 g/kg NDF, 249 - 253 g/kg ADF) (irrespective of DE level) had increased total VFA and acetic acid concentration. This high total VFA produced by rabbits fed with high fibre resulted from greater quantity of fibre fermentation. The increased acetic acid concentration generated with increasing dietary fibre level agreed with the findings of Chao and Li (2008). The concentration of

total VFA and proportion of acetic acid produced increased with reduction in propionic and butyric acid level as the dietary fibre level is enhanced (Gidenne *et al.*, 2000). Tao and Li (2006) also confirmed that fibrolytic activities in the caecum of growing rabbits increased as the dietary NDF increased leading to higher production of energy. Increased fibrolytic activities have been reported to improve growth and the health of the rabbits. Peters *et al.* (1995) found a high VFA levels and a reduced P^H of the caecal contents in rabbits resulting in a protective effect against experimental enteropathoganc *E coli* infection.

In conclusion, this study showed that (430 – 456 g/kg NDF, 249 - 253 g/kg ADF) diets in rabbit nutrition improved growth performance, nutrient digestibility and increased caecal fermentation. Rabbits fed diets containing (445.70 g/kg NDF, 252.10 g/kg ADF and 8.01 MJ/Kg) had the highest weight gain, improved feed to gain ratio and caecal fermentation.

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