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Effect of Varying NDF, ADF and Digestible Energy Levels on Growth Performance, Nutrient Digestibility, Caecal Fermentation, Caecal and Faecal Microflora of Growing Rabbits

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Strictly as per the compliance and regulations of :

Effect of Varying NDF, ADF and Digestible Energy Levels on Growth Performance, Nutrient Digestibility, Caecal Fermentation, Caecal and Faecal Microflora of Growing Rabbits

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Abstract - A t otal of 135 weaner rabbits were used in a 70 days feeding trial to investigate the effect of Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and digestible energy (DE) levels on growth performance, nutrient digestibility, caecal fermentation, caecal and faecal microflora. The experiment was laid out in a 3 × 3 factorial arrangement of 3 levels of fibre components (low, optimum and high) and 3 levels of DE (low, optimum and high). There were 9 dietary treatments with 15 rabbits allotted to each diet. Final liveweight ($P<0.01$) and weight gain ($P<0.05$) of rabbits increased with increasing dietary fibre. Rabbit fed high DE diets recorded the highest ($P<0.05$) weight gain. Rabbits fed high fibre + low DE diet had the highest final live weight ($P<0.001$), weight gain ($P<0.001$) and feed intake ($P<0.05$). Rabbits fed with high fibre diets recorded the highest ($P<0.05$) caecal total VFA and acetic acid concentration. Lactobacillus count of the caecum content increased ($P<0.001$) with increasing level of dietary fibre. High fibre diets increased caecal fermentation, caecal lactobacillus and total bacterial count. Feeding of high fibre + low DE diets showed highest weight gain, improved feed to gain ratio and caecal fermentation.

Keywords : growing rabbits, dietary fibre, caecal fermentation, total bacterial count, lactobacillus count.

I. Introduction

Fibre is regarded as one of the main constituents of rabbit feed ranging from 150 g/kg to 500 g/kg (Gidenne, 2003). A dietary fibre level of 335 - 400 g/kg NDF, 170 g/kg ADF (De Blas and Mateus, 1998) and a daily intake of 6 g lignin (Dalle Zotte, 2002) were recommended for a growing rabbit. In rabbit nutrition, to formulate a ration that is balanced in fibre mostly leads to a compromise in energy. This is because fibrous ingredients are mostly characterized with low energy (Gidenne *et al.,* 2000). Excessive fibre intake has been reported to cause reduced feed efficiency and poor nutrient digestibility (Nicodemus *et al.,* 1999). On the other hand, intake of high energy diets (mostly at the expense of fibre) resulted in incidence of digestive disturbances, loss of appetite and reduced feed conversion ratio (Bennegadia *et al.,* 2001). An appropriate balance between dietary fibre and energy is therefore crucial to optimal growth and health of rabbits. Dietary fibre level were reported in previous studies to affect growth (Tao and Li, 2006), nutrient digestibility, caecal fermentation, fibrolytic activities (Falcao-e-Cunha *et al.,* 2004) and gut microflora population (Fortun-Lamothe and Boullier, 2007). The gut microbial activity determines the concentration of volatile fatty acids (VFA) generated in the rabbit caecum (Bellier and Gidenne, 1996). Intake of fibrous diet was reported to affect gut microflora count in rabbits (Oso *et al.,* 2011) and lead to high bacterial shedding in the faeces of pigs (Chen *et al.,* 1998). Research studies aimed at investigating the interactive effect of fibre components and digestible energy (DE) levels on caecal fermentation, gut and faecal microflora of growing rabbits are rare. This study therefore seeks to investigate the main effect, interaction effect of varying fibre components (NDF, ADF) and digestible energy on growth performance, nutrient digestibility, caecal fermentation, gut and faecal microflora of growing rabbits.

II. Materials and Methods

a) Experimental diets and Management

The study was carried out at the Rabbit Unit of the Teaching and Research Farm of the University of Agriculture, Abeokuta, Nigeria, West Africa. It is located 76 m above sea level and falls within latitude 7°15′ North and longitude 3°21′ East. Nine experimental diets were formulated in a 3 × 3 factorial arrangements having three levels of fibre components {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

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DE levels {low (8 – 8.5 MJ/kg), optimum (10.5 – 11 MJ/kg) and high (12 – 12.30 MJ/kg)} (Table 1). Dietary NDF and ADF levels regarded as low (Gidenne *et al.,* 2004; Pinheiro *et al.,* 2009) and optimum (De Blas and Mateous, 1998; Chao and Li, 2008) in the current study were as reported in previous findings. Digestible energy levels of diets similar or close to values recommended for maximum rabbit meat production was considered as optimum (INRA, 1989; Lebas, 1991).

b) Growth response and metabolic trial

A total of one hundred and thirty five, 5 weeks old, male weaner rabbits, of mixed breeds with a mean body weight of 448.14 $\pm$ 16.05 (SEM) g were randomly allotted to 9 dietary groups of 15 rabbits each. The feeding trial lasted for 70 days. A total of 27 fabricated wired rabbit hutches (each of dimension 200 cm $\times$ 80 cm $\times$ 80 cm (LWH)) were used in all for the study. Each hutch was partitioned into 5 equal cage units. A total of 3 hutches were assigned to a treatment. Feed intake and live weight were recorded per rabbit housed in each cage unit. The total feed intake, weight gain and the feed to gain ratio were also computed. At the end of the feeding trial, 6 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 4 days. Excreta (free of feed particles and other contaminants) were collected daily from each cage and dried overnight (at 60°C for 12 hours). Feed samples and dried excreta samples (n=5 per treatment) were analyzed for proximate constituents according to the Official Methods of Association of Analytical Chemists (AOAC 1990). The fibre fraction (NDF, ADF, ADL) of the samples were determined as described by Van Soest *et al.* (1991). The gross energy of the samples was determined using the ballistic bomb calorimeter.

c) Caecal Fermentation

At 70 days of age, 6 rabbits were selected at random without prior fasting from each treatment and slaughtered between 5–7 hours after the beginning of daily light period for the collection of caecal content. About 10g of caecum content was collected from each rabbit. The caecal content collected was divided into two, half was immediately used for caecal fermentation while the rest used for microbial analysis. The caecal content meant for microbial analysis were placed under a stream of CO_2, stored in separate plastic bottles and immediately transported to the laboratory for microflora count For the determination of VFA concentration, a solution of 5% orthophosphoric acid (v/v) plus 1% mercury chloride (w/v) was added to the caecal content samples. Volatile fatty acids were measured by gas chromatography, with a gas column: free fatty acids and phenols 10% H_3PO_4, 1% acid-washed chromosorb W, 100 - 120 mesh. The carrier gas was N_2 with a flow rate of 40 ml/min: H_2 and air flows to the detector were 60 ml/min. Injector and detector temperatures were 250°C while the oven temperature was 150°C.

d) Faecal and caecal microbial count

At 60 days of age, light plastic collars were put around the neck of 6 rabbits randomly selected from each treatment at 08:00. These collars were taken out after 2 set samples of 4 - 5 g of ceacotrophs had been collected per rabbit. The fresh ceacotroph samples collected were placed under a stream of CO_2, stored in separate plastic bottles for microflora count Microbial counts of the faecal sample and caecal content were determined according to the methods of Xia *et al.* (2004). Approximately 1 g of fresh sample (faecal and caecal content) was dispersed in 9 ml phosphate buffered saline solution supplemented with 0.5 g/l Cysteine-hydrochloride, thoroughly mixed and further diluted to factor 10^{-8}. From this material, each 0.1 ml was spread on sterile Petri dishes containing selective media and incubated for analysis of total microbial colony count using the Plate-count agar incubated at 30°C, for 72 hours, Coliform (ES agar, 37°C, 24 hours, Merck, Darmstadt), lactobacilli (MRS-agar 37°C, 72 hours, Merck, Darmstadt), Clostridia (Wilkins-Chalgren Agar + Novobiocin (8 mg/l) + Colistin Sulfate (8 mg/l), 37°C, 72 hours). Colony forming units (CFU) were counted. Colony counts were calculated on the base of 1 g of sample and then transformed as $\log_{10}$ of viable bacteria per gram of fresh matter.

e) Statistical Analysis

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. Microbial counts initially expressed as coliform units per gram (CfU/g) were transformed into logarithm ($\log_{10}$). Mean values showing significant ($P<0.05$) differences in the ANOVA were compared using Duncan's multiple range test as described by Duncan (1955).

III. Results

a) 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 liveweight (P<0.01) and weight gain (P<0.05) increased with increasing dietary fibre level. Rabbits fed with high fibre recorded the highest feed intake (P<0.05), final liveweight (P<0.01) and weight gain (P<0.05). However, rabbits fed with low fibre had the worst (P<0.05) feed to gain ratio. Highest (P<0.05) apparent dry matter, ether extract digestibility, NDF and ADF digestibility were obtained with rabbits fed diet containing optimum fibre. 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 had the least ($P<0.05$) apparent dry matter, ash, crude protein, NDF and ADF digestibility. Rabbit fed optimum digestible energy diets recorded the highest ($P<0.05$) apparent dry matter, ash, crude protein, ether extract, NDF and ADF digestibility values. Interaction of dietary fibre and DE levels showed highest final liveweight ($P<0.001$), weight gain ($P<0.001$) and feed intake ($P<0.05$) with rabbits fed high fibre + low DE (Table 3). Rabbits fed diet containing low fibre + low DE had the least ($P<0.001$) final liveweight, weight gain, apparent dry matter and ADF digestibility. Highest ($P<0.05$) apparent NDF digestibility was obtained with rabbits fed diets containing optimum fibre + optimum DE while highest ($P<0.001$) ADF digestibility obtained with rabbits fed with high fibre + high DE.

b) Ceacal fermentation, caecal and faecal microflora

The main effect of dietary fibre and DE level on caecal fermentation, caecal and faecal microflora 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. Rabbits fed with low DE recorded the least ($P<0.05$) total volatile fatty acid. Main effect of dietary fibre also showed that Lactobacillus counts of the caecum content increased ($P<0.01$) with increasing level of dietary fibre. Rabbit fed high fibre diets recorded the highest caecal ($P<0.01$) lactobacillus and total bacterial count. The least faecal ($P<0.05$) lactobacillus count was obtained from caecotroph samples of rabbits fed low fibre diets. The faecal samples of rabbits fed with low DE diets also showed the highest ($P<0.05$) lactobacillus count.

Interaction effect of dietary fibre and digestible energy level on caecal fermentation, caecal and faecal microfloral of rabbits is shown in Table 5. Irrespective of the DE level of the diets, all rabbits fed high fibre diets showed the highest ($P<0.05$) total VFA, acetic acid concentration and high ($P<0.01$) caecal total bacterial counts. Rabbits fed low fibre + high DE and those fed high fibre + high DE showed similar lactobacillus count in the caecal content. Rabbit fed low fibre + optimum DE, low fibre + high DE, optimum fibre + optimum DE and high fibre + high DE showed no presence of Lactobacillus spp.

IV. Discussion

Improved growth response obtained in the current study with rabbits fed diet containing high fibre + low DE agreed with previous findings that rabbits can be sustained on high fibre diets (De Blas *et al.,* 1995; Tao and Li, 2006). The findings of this study also agreed with Pinheiro *et al.* (2009) who reported improved growth performance with growing rabbits fed diets containing 233 g/kg ADF and 73 g/kg ADL. Improved feed conversion ratio obtained with rabbits fed high fibre + low DE diet also agreed with the report of Nguyen and Nguyen (2008) who concluded that dietary inclusion of up to 410 g/kg NDF in rabbits gave higher growth rates and better benefits for rabbit producers. Highest feed intake obtained with rabbits fed high fibre + low DE diet agreed with previous findings that rabbits have the ability to adjust its voluntary intake in response to changes in dietary energy concentration (Patridge *et al.,* 1989). Rabbits fed high fibre diets tend to consume more to meet its energy requirement. Poor growth noticed with rabbits fed low fibre diets in this study agreed with previous findings (Bennegadia *et al.,* 2001).

The improved apparent dry matter, ash and NDF digestibility obtained with rabbits fed diet containing optimum fibre + optimum DE could be due to the fact that dietary fibre and DE at this level lied within the recommended level (Lebas, 1991; Gidenne *et al.,* 2001). The proportion of the low digestible fibre (cellulose, lignin) and high digestible fibre (hemicellulose) at this level was also considered to be adequate for growing rabbits (Gidenne and Perez, 2003). The degree of lignification (Gidenne and Perez, 1994) and lignocellulose ratio (Gidenne *et al.,* 2001) of the diet containing optimum fibre + optimum DE diet were also adequate for growing rabbits and could be contributory to the improved nutrient digestibility obtained.

Volatile fatty acids (VFAs) produced as a result of caecal fermentation of digestible fibre or undigested nutrients provide a vital source of energy for the rabbits (Nicodemus *et al.,* 1999). High total VFA and acetic acid concentration generated from the caecum content of rabbits fed high fibre diets resulted from greater quantity of fibre fermentation (Chao and Li, 2008). Gidenne *et al.,* (2000) reported that the concentration of caecal total VFA and proportion of acetic acid produced increased as the dietary fibre level is enhanced. Tao and Li (2006) also confirmed that fibrolytic activities in the caecum of growing rabbits increased as the dietary NDF increased resulting in higher production of energy. Increased fibrolytic activities have been reported to improve growth and the health of the rabbits as Peters *et al.* (1995) found a high caecal VFA in rabbits resulting in a protective effect against experimental enteropathogenic *E. coli* infection.

Bacteria constituted the most dominant of the gut microbiota in rabbits (Boulharouf *et al.,* 1991). A stable gut microflora is reported to be responsible for increased caecal fermentation, improved growth and reduced digestive disorders (Gidenne, 1996). High caecal lactobacillus and total bacterial count obtained from rabbits fed high fibre diets could be linked with the NDF level and botanical source (Belenguer *et al.,* 2000).

Dietary NDF was reported as one of the most crucial factors regulating microbial activity within the caecum of rabbits (De Blas *et al.,* 1999). Increased lactobacillus and bacterial count obtained with high fibre intake favoured high fibrolytic activity (Gidenne *et al.,* 2004) and improved the health status of rabbits (Debray *et al.,* 2002; Oso *et al.,* 2011). Previous findings also reported increased fibrolytic activity of caecal bacteria when dietary crude fibre increased from 110 g/kg to 170 g/kg in rabbits (Boulahrouf *et al.,* 1991). However, low enteric microbial population was reported to be implicative of impaired growth of animals (Davis *et al.,* 2003).

High lactobacillus count obtained from the faecal samples of rabbits fed high fibre diets resulted from high digesta passage rate created as a result of high fibre intake. High fibre intake lowers the duration of contact between digesta and the intestinal bacteria for effective digestion hence more of the bacteria will be shed in the faeces. Excessively fibrous diets have been reported to reduce microbial activity by increasing the digesta transit rate (Robertson, 1988).

Table 1 : Gross composition of experimental diets

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 ingredients 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
Crude protein									
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
Digestibleenergy (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 cyanacobalamin. [b]Calculated using deBlas et al.,, (1992) (DE=GE × (0.867-0.0012ADF))

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

	Main effect of Fibre			Main effect of digestible energy		
Parameters	Low	Optimum	High	Low	Optimum	High
Final live weight (g/rabbit)	903.93±24.50[c]	1087.13±41.90[b]	1144.83±74.10[a]	1053.90±43.2	1036.00±42.1.9	1046.00±44.80
Feed Intake (g/rabbit)	1716.67±61.00[b]	1691.67±35.00[c]	1749.90±29.70[a]	1758.33±28.20[a]	1661.00±52.4[c]	1738.90±42.70[b]
Weight gain (g/rabbit)	463.77±25.60[c]	650.00±19.9[b]	739.37±34.50[a]	603.30±23.70[b]	599.97±23.4[b]	649.87±46.4[a]
Feed to gain ratio	3.70±0.13[a]	2.60±0.16[b]	2.37±0.27[b]	2.91±0.39	2.77±0.33	2.68±0.22
Apparent nutrient digestibility (%)						
Dry matter	76.9±3.57[b]	78.50±2.96[a]	74.35±1.45[c]	70.23±2.17[c]	81.23±2.02[a]	78.32±2.79[b]
Ash	64.83±5.43[a]	65.70±6.62[a]	58.66±2.69[b]	52.95±3.15[c]	69.81±3.35[a]	66.42±4.56[b]
Ether extract	91.43±9.98[b]	94.30±2.86[a]	92.14±7.63[b]	89.32±1.56[b]	94.51±6.35[a]	66.42±4.56[c]
Crude protein	81.26±2.20	81.12±3.21	80.21±2.07	78.88±0.67[c]	82.73±8.67[a]	80.98±1.15[b]
NDF	55.12±9.83[b]	57.88±4.13[a]	53.31±1.61[c]	48.96±2.68[c]	60.36±7.97[a]	56.99±2.96[b]
ADF	44.60±7.62[b]	46.92±4.55[a]	41.63±2.11[c]	34.82±3.50[c]	51.51±5.83[a]	46.81±4.44[b]

[a,b,c] *Means on the same row with different superscripts are different significantly (P<0.05)*

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

Fibre level	Low			Optimum			High		
Digestible energy level	Low	Optimum	High	Low	Optimum	High	Low	Optimum	High
Finalweight (g/rabbit)	811.80±26.60[h]	850.00±22.43[g]	1050.00±82.10[e]	1125.00±92.17[c]	1070.70±86.99[d]	1065.70±81.65[d]	1224.90±92.17[a]	1187.30±99.69[b]	1022.30±88.19[f]
FeedIntake (g/rabbit)	1750.00±54.40[c]	1700.00±44.43[e]	1700.00±63.41[e]	1650.00±44.43[f]	1700.00±62.08[e]	1725.00±48.87[d]	1875.00±68.87[a]	1583.00±67.29[g]	1791.70±66.43[b]
Weightgain (g/rabbit)	366.30±26.70[f]	412.50±43.30[e]	612.50±32.17[d]	668.80±25.25[c]	668.60±39.69[c]	612.60±43.35[d]	774.80±37.12[a]	718.80±33.51[b]	724.50±28.50
Feed to gain ratio	4.78±0.83[a]	4.12±0.41[a]	2.78±0.37[b]	2.47±0.09[b]	2.54±0.13[b]	2.82±0.10[b]	2.42±0.39[b]	2.20±0.49[b]	2.47±0.44[b]
Apparent nutrient digestibility(%)									
Dry matter	63.40±1.98[e]	79.70±0.91[b]	87.67±0.21[a]	78.30±1.99[b]	88.87±1.01[a]	68.34±1.01[d]	69.00±2.01[d]	75.11±0.90[c]	78.95±0.72[b]
Ash	44.38±0.78[e]	68.67±0.77[b]	81.43±0.85[a]	65.23±1.00[c]	81.94±2.20[a]	49.94±1.02[d]	49.23±1.03[d]	38.82±0.99[f]	67.90±3.01[b]
Ether extract	83.67±2.01	77.88±3.01	86.62±1.93	78.44±2.77	97.22±4.01	91.25±5.03	89.85±3.02	92.36±4.04	94.22±2.20
Crude protein	76.64±2.96	82.28±2.09	84.85±4.03	81.24±2.05	85.25±3.03	76.88±2.01	78.77±1.99	80.67±2.44	81.20±2.55
NDF	40.85±2.22[e]	57.88±3.01[b]	46.62±2.00[d]	58.78±2.33[b]	68.08±1.55[a]	46.57±1.75[d]	47.04±1.99[d]	55.11±2.02[d]	59.77±3.01[b]
ADF	23.34±0.76[g]	48.85±0.89[c]	41.60±0.72[d]	47.49±1.59[c]	62.39±1.51[b]	30.88±0.88[f]	33.64±0.21[e]	42.30±0.78[d]	67.96±2.02[a]

[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, caecal and faecal microflora of rabbits

	Main effect of fibre			Main effect of digestible energy		
Paramete rs	Low	Optimum	High	Low	Optimum	High
Caecal VFA (mmol/100ml)						
Total	4.53±0.12^{c}	6.33±0.19^{b}	8.17±0.97^{a}	5.80±0.22^{b}	6.60±0.59^{a}	6.63±0.26^{a}
Acetic	2.96±0.07^{c}	4.50±0.19^{b}	5.70±0.45^{a}	3.97±0.92	4.67±0.67	4.50±0.64
Propionic	0.33±0.09	0.53±0.01	0.70±0.04	0.50±0.09	0.57±0.05	0.53±0.19
Butyric	0.73±0.02	0.96±0.01	1.13±0.09	0.83±0.06	1.07±0.07	0.93±0.01
Caecal microflora ($\log_{10}$)						
Coliform	9.10±0.11	8.99±0.01	8.66±0.24	8.99±0.1	8.76±0.27	8.99±0.01
Clostridium	8.72±0.01	8.72±0.03	8.69±0.01	8.67±0.02	8.75±0.02	8.73±0.01
Lactobacillus	1.99±0.99^{c}	4.26±1.07^{b}	6.40±0.40^{a}	4.30±1.08	2.20±1.10	6.15±0.08
Total bacterial count	10.02±2.44^{b}	10.39±2.66^{b}	12.34±2.95^{a}	10.60±1.96	10.90±1.18	11.24±2.22
Faecal micrflora ($\log_{10}$)						
Coliform	7.97±0.99	8.93±0.03	8.96±0.80	8.96±0.80	8.96±0.60	7.93±0.99
Clostridium	8.65±0.02	8.60±0.08	8.62±0.04	8.68±0.01	8.59±1.08	8.59±0.04
Lactobacillus	2.20±0.10^{b}	3.99±0.11^{a}	3.60±0.14^{a}	5.53±1.71^{a}	2.16±0.82^{b}	2.10±0.105^{b}
Total bacterial count	10.09±1.10	10.11±0.98	10.79±1.09	10.29±0.74	10.21±0.78	10.48±1.25

[a,b,c] *Means on the same row with different superscripts are different significantly ($P<0.05$)*

Table 5 : Interaction effect of varying dietary fibre and digestible energy on caecal fermentation, caecal and faecal microflora of rabbits

Fibre level	Low			Optimum			High		
Digestible energy level	Low	Optimum	High	Low	Optimum	High	Low	Optimum	High
Caecal VFA									
Total (mmol/100ml)	4.20 ± 0.67^{d}	4.60 ± 0.29^{c}	4.80 ± 0.91^{c}	5.00 ± 0.62^{c}	6.80 ± 0.16^{b}	7.20 ± 0.71^{b}	8.20 ± 0.93^{a}	8.40 ± 0.74^{a}	7.90 ± 0.90^{a}
Acetic (mmol/100ml)	2.70 ± 0.83^{c}	3.20 ± 0.14^{c}	3.00 ± 0.99^{c}	3.50 ± 0.66^{c}	4.90 ± 0.67^{b}	5.10 ± 0.73^{b}	5.70 ± 0.24^{a}	5.90 ± 0.88^{a}	5.50 ± 0.41^{a}
Propionic (mmol/100ml)	0.30 ± 0.05	0.40 ± 0.09	0.40 ± 0.07	0.50 ± 0.08	0.50 ± 0.05	0.60 ± 0.07	0.70 ± 0.04	0.80 ± 0.03	0.60 ± 0.05
Butyric (mmol/100ml)	0.70 ± 0.01	0.70 ± 0.09	0.80 ± 0.06	0.70 ± 0.09	1.20 ± 0.02	1.00 ± 0.09	1.10 ± 0.29	1.30 ± 0.61	1.00 ± 0.03
Caecal microflora									
Coliform (log_{10})	8.99 ± 0.09	9.30 ± 0.12	8.99 ± 0.07	8.99 ± 0.05	8.99 ± 0.02	8.99 ± 0.01	8.99 ± 0.11	8.00 ± 0.10	8.99 ± 0.07
Clostridium (log_{10})	8.70 ± 0.12	8.77 ± 0.10	8.70 ± 0.19	8.61 ± 0.11	8.78 ± 0.07	8.77 ± 0.22	8.69 ± 0.91	8.69 ± 0.19	8.70 ± 0.10
Lactobacillus (log_{10})	0 ± 0.00^{c}	0 ± 0.00^{c}	5.99 ± 0.12^{b}	6.30 ± 0.17^{b}	0 ± 0.00^{c}	6.48 ± 0.15^{a}	6.60 ± 0.19^{a}	6.60 ± 0.39^{a}	5.99 ± 0.22^{b}
TBC (log_{10})	10.04 ± 1.44^{c}	10.02 ± 0.96^{c}	10.00 ± 0.77^{c}	10.09 ± 0.94^{c}	10.01 ± 1.22^{c}	11.02 ± 0.84^{b}	11.67 ± 0.95^{ab}	12.65 ± 1.92^{a}	12.70 ± 1.88^{a}
Faecal microflora									
Coliform (log_{10})	8.96 ± 0.93	8.96 ± 0.77	5.98 ± 0.89	8.96 ± 0.79	8.97 ± 0.66	8.96 ± 0.65	8.97 ± 1.02	8.96 ± 0.97	8.96 ± 0.88
Clostridium (log_{10})	8.71 ± 1.09	8.61 ± 0.99	8.61 ± 0.90	8.63 ± 0.88	8.46 ± 0.29	8.70 ± 0.44	8.70 ± 0.69	8.70 ± 0.90	8.70 ± 0.99
Lactobacillus (log_{10})	6.61 ± 0.85^{a}	0 ± 0.00^{d}	0 ± 0.00^{d}	5.66 ± 0.90^{b}	0 ± 0.00^{d}	6.30 ± 0.45^{a}	4.33 ± 0.29^{c}	6.48 ± 0.22^{a}	0 ± 0.00^{d}
TBC (log_{10})	10.00 ± 0.94	10.12 ± 1.09	10.02 ± 0.77	10.10 ± 0.90	10.00 ± 0.60	10.22 ± 0.89	10.67 ± 0.90	10.50 ± 0.77	11.20 ± 1.01

[a,b,c,d] *Means on the same row with different superscripts are different significantly ($P<0.05$)*

V. Conclusion

High fibre diets (containing low or optimum DE) in rabbit nutrition improved growth performance, nutrient digestibility, increased caecal fermentation and favoured high caecal lactobacillus and total bacterial count. Rabbits fed diets containing high fibre + low DE showed the highest weight gain, improved feed to gain ratio and caecal fermentation.

References Références Referencias

1. A.O.A.C. 1990. The Official Method of Analysis. Association of Official Analytical Chemists, 5th edition. pp. 68-88. Arlington.
2. Belenguer, A., Fondevila, M., Balcells, J. and Torre, C. 2000. Effect of the source and level of cereal in diet on the rabbit caecal environment and microbial population. In: Proceedings of the 7th World Rabbit Congress, Valencia, Spain. pp. 95–100.
3. Bellier, R. and Gidenne, T. 1996. Consequence of reduced fibre intake on digestion, rate of passage and caecal microbial activity in the young rabbit. *British Journal Nutrition* 75, 353–363.
4. Bennegadia, N., Gidenne, T. and Licois, D. 2001. Impact of fibre deficiency and sanitary status on non-specific enteropathy of the growing rabbit. *Animal Research* 50, 401–413.
5. Boulahrouf, A., Fonty, G. and Gouet, P. 1991. Establishment, counts and identification of the fibrolytic bacteria in the digestive tract of rabbit. Influence of feed cellulose content. *Curr. Microbiology*. 22, 1–25.
6. Chao, H.Y. and Li, F.C. 2008. Effect of level of fibre on performance and digestion traits in growing rabbits. *Animal Feed Science and Technology* 144, 279-291.
7. Chen, H.L., Haack, V.S., Janecky, C.W., Vollendorf, N.W. and Marlett, J.A. 1998. Mechanism by which wheat bran and oat bran increase stool weight in humans. *American Journal of Clinical Nutrition* 68, 711-719.
8. Dalle Zotte, A. 2002. Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. *Livestock Production Science* 75, 11-42.
9. Duncan, D.B. 1955. Multiple range and F test. *Biometrics* 11, 1–42.
10. Davis, M.E., Brown, D.C., Maxwell, C.V., Rehberger, T.,Touchette, K.J. and Coalson, J.A. 2003. Influence of *Lactobacillus brevis* 1E-1 on the gastrointestinal microflora, gut morphology, and performance pre- and post-weaning. In: Proceedings of the 9th International Symposium on Digestive Physiology in Pigs. Banff, AB, Canada pp.265-267.
11. De Blas, J.C., García, J. and Carabaño, R 1999. Role of fibre in rabbit diets. *Annals de Zootechnica* 48, 3-13.
12. De Blas, J.C. and Mateous, G.G. 1998. Feed formulation. In: de Blas, J.C., Wiseman, J. (Eds.), The Nutrition of the Rabbit. CABI International, Wallingford, UK, pp. 241– 253.
13. De Blas, J.C., Taboada, E., Mateos, G.G., Nicodemus, N. and Mendez, J. 1995. Effect of substitution of starch for fibre and fat in isoenergetic diets on nutrition digestibility and reproductive performance of rabbits. *Journal of Animal Science* 73; 1131 – 1137.
14. DeBlas, J.C., Wiseman, M., Fraga, M.J. and Villamide, M.J. 1992. Prediction of the digestible energy and digestibility of gross energy of feeds for rabbits. *Animal Feed Science Technology* 39, 39–59.
15. Debray, L., Fortun-Lamothe, L. and Gidenne, T. 2002. Influence of low dietary starch/fibre ratio around weaning on intake behaviour, performance and health status of young and rabbit does. *Animal Research* 51, 63–75.
16. Falcao-e-Cunha, L., Helena Peres, J., Joao, P.B. and Freire, L.C. 2004. Effects of alfalfa, wheat bran or beet pulp, with or without sunflower oil, on caecal fermentation and on digestibility in the rabbit. *Animal Feed Science and Technology* 117,131– 149.
17. Fortun-Lamothe, L. and Boullier, S. 2007. A review on the interactions between gut microflora and digestive mucosal immunity. Possible ways to improve the health of rabbits. *Livestock Production Science* 107, 1–18.
18. Gidenne, T. 1996. Nutritional and ontogenic factors affecting the rabbit caeco-colic digestive physiology. In: Lebas, F (Ed). Proceedings of the World rabbit congress. INRA. Touzlouse, pp. 13-28.Gidenne, T. 2003. Fibres in rabbit feeding for digestive troubles prevention: respective role of low-digested and digestible fibre. *Livestock Production Science* 66, 105–117.
19. Gidenne, T., Arveux, P. and Madec, O. 2001. The effect of the quality of dietary lignocellulose on digestion, zootechnical performance and health of the growing rabbit. *Animal Science*. 73, 97–104.
20. Gidenne, T., Mirabito, L., Jehl, N., Perez, J.M., Arveux, P., Bourdillon, A., Briens, C., Duperray, J. and Corren, E. 2004. Impact of replacing starch by digestible fibre, at two levels of lignocellulose, on digestion, growth and digestive health of the rabbit. *Animal Science* 78, 389–398.
21. Gidenne, T. and Perez, J.M. 1994. Apports de lignines et alimentation du lapin en croissance. 1.Cons´equences surla digestion et le transit. *Annals de Zootechnica*. 43, 313–322.

22. Gidenne, T., Pinheiro, V. and Falcao-e-Cunha, L. 2000. A comprehensive approach of the rabbit digestion: consequences of a reduction in dietary fibre supply. *Livestock Production Science*. 64, 225 –237.
23. INRA, 1989. Alimentation des animaux monogastriques: port, lapin, volailles. 2nd edition, INRA publ., Paris.
24. Lebas, F. 1991. Alimentation pratique des lapins en engraissement. *Cuniculture*, 18, 273- 281.
25. Nguyen, T.K. and Nguyen, T.G. 2008. Effect of different levels of NDF in the diets on feed utilization, growth rate and nutrient digestibility of growing crossbred rabbits. Vietnam.MEKARN Proceedings of Workshop on Organic rabbit production from forages. Cambodia, 22-24 August 2008. Agricultural Publishing House, Hanoi. pp176- 182.
26. Nicodemus, N., Carabano, R., Garcıa, J., Mendez, J. and De Blas, C. 1999. Performance responseof lactating and growing rabbits to dietary lignin content. *Animal Feed Science and Technology* 80, 43–54.
27. Oso, A.O., Sobayo, R.A., Jegede, A.V., Fafiolu, A.O., Iyasere, O.S., Dele, P., Bamgbose, A.M. and Cecilia, A. 2011. Effect of dietary inclusion of sorghum milling waste on growth response, nutrient utilisation, gut characteristics and cecal microflora of weaner rabbits. *Animal Science Journal* (Japan) 82, 468-474.
28. Partridge, G., Ganhawaite, P.H. and Findlay, M. 1989. Protein and energy retention by growing rabbits offered with increasing proportions of fibre. *Journal of Agricultural Science* 112, 171- 178.
29. Peters, J.E., Maertens, L., Orsenigo, O. and Colin, M. 1995. Influence of dietary beet pulp on caecal VFA, experimental colibacillosis and iota-enterotoxaemia in rabbits, *Animal Feed Science and Technology* 51, 123–139.
30. Pinheiro, V., Guedes, C.M., Outor-Monteiro, D. and Mourao, J.L. 2009. Effects of fibre level and dietary mannanoligosaccharides on digestibility, caecal volatile fatty acids and performances of growing rabbits. *Animal Feed Science and Technology* 148, 288- 300.
31. SAS, 2003. SAS Proprietary Software, SAS Institute, Inc. Release 9.1, Cary, NC.
32. Tao, Z.Y. and Li, F.C. 2006. Effects of dietary neutral detergent fibre (NDF) on production, nutrient utilization, caecum fermentation fibrilytic activity in 2-3months Newzealand Rabbits. *Journal of Animal Nutrition and Animal Physiology*. 90, 467-473.
33. Van Soest, J.P., Robertson, J.B. and Lewis, B.A. 1991. Methods for dietary fibre, neutral detergent fibre and non starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science.* 74, 3583–3594.
34. Xia, M.S., Hu, C.H. and Xu, Z.R. 2004. Effect of copper-bearing montmorillonite on growth performance, digestive enzyme activities, and intestinal microflora and morphology of male broiler. *Poultry Science* 83, 1868–1875.

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