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NUTRIENTS DIGESTABILITY, FUNCTION AND DEVELOPMENT OF GASTROINTESTINAL TRACT (GIT) IN RABBITS FED DIFFERENT LEVELS OF CRUDE FIBER

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SUMMARY

A total number of 45 California rabbits were used in this experiment to investigate the effect of different dietary crude fiber levels on nutrients digestibility, anatomical characteristics of gastrointestinal tract (GIT) and performance. Animals were allocated into 3 different groups according to dietary fiber levels; moderate fiber diet considered as a control (MF, 15%), low fiber diet (LF, 11%) and high fiber diet (HF, 19%). The experimental diets were isocaloric isonitrogenous (2596 Kcal DE/kg and 15% CP). Animals were fed treatment diets from weaning (1.5 month) to 5 months of age. Body weight, feed intake were recorded weekly and feed conversion and daily gain were calculated. While, total digestible nutrients (TDN) and digestibility coefficients were measured at the end of the experiment. Six animals were slaughtered from each group at ages 3 and 5 months for gastrointestinal and carcass characteristics.

Results indicated that body weight; body gain and feed conversion were slightly lower in HF and MF fed animals during the first 4 weeks post weaning. While a slight increase in these parameters were found in the same group during second 4 weeks. Values of the TDN and digestibility coefficients of most nutrients were higher ($p < .05$) in LF and MF compared to HF fed group. Mortality rate was high in LF compared to MF or HF fed groups, 40% vs. 6% or 0.0%, respectively. Carcass cut-up parts indicated higher ($p < .05$) absolute weight of head, hindlimbs, liver and integument in both LF and MF compared to HF fed groups. Total weight of gastrointestinal tract (GIT) was increased in HF fed group at 5 month-old mainly due to the weight of both cecum and stomach. Stomach volume of LF fed rabbits was decreased significantly ($p < .05$) by 37 and 21% compared to HF and MF fed rabbits, respectively. The anatomical volume of the intestine tended to be higher in LF fed group, mostly due to an increase in cecum volume. In conclusion, feeding young rabbits a high fiber diet until maturity is very important in determining the depressive effect on digestibility of non-fiber components due to some characteristics changes in the GIT.

Keywords: Crude fiber, diet- performance, TDN, rabbit

INTRODUCTION

Alfalfa hay is a common practice in rabbit's diet at high levels without noticeable harm effect. Rabbits maintained on low- fiber diets have prolonged cecal retention time, reduced feed intake and a predisposition to diarrhea Laplace (1978). The levels of fiber in terms of their ability to meet requirements and maintain health of the rabbits have been extensively studied since the late 1970s. Recently, inadequate information considering updating the nutrient requirements is available. Lebas (1980) stated the essential crude fiber requirement to be 14% for does and growing rabbits. While, de Blas *et al.* (1986) recommended a minimum of 10% CF for maximum growth of fryers. In addition, excess level of 17% crude fiber would depress growth through restricting energy intake. Growth rate was also reduced in fryers rabbits fed low- fiber diet Champe and Maurice (1983), Cheek and Patton (1980), de Blas *et al.* (1986), Lebas and Laplace (1977) and Pote *et al.* (1980). Growth rate was optimal when dietary crude fiber ranged from 10 to 15% de Blas *et al.* (1986). The effect of alfalfa meal supplementation to cereal- based diet was found to give maximum response when compared to diet based solely on cereal grains Pote *et al.* (1980). Small rabbit's fryers, can rapidly adapt to changes within 2-weeks when diet was switched from high energy (20 % alfalfa) to low energy diet (54% alfalfa). Hence, low mortality and improved feed efficiency were obtained Grobner *et al.* (1985).

Garabano *et al.* (1997) replaced 30% of dietary alfalfa hay by sugerbeet pulp (up to 300g kg^{-1}) and found little effect on digestive traits and digestible energy efficiency for growth. Rabbits can regulate their energy intake in the long-term even when fed different levels of fiber and different DE contents. The purpose of this study was to examine some of the benefits, limitations and effects of feeding different levels of fibrous feedstuffs with emphasis on the alfalfa hay with equal DE contents of diets.

MATERIALS AND METHODS

Forty five weaned (6 week-old) California rabbits with homogenous body weights (940 ± 51.11 g) were used in this experiment to investigate the effect of dietary fiber on performance and anatomical characteristics and function of gastrointestinal tract. Rabbits were housed in stainless steel batteries for 3 months and maintained on a 14/ 10 light/ dark cycle using incandescent lighting with appropriate ventilation. Animals were fed 3 diets, isocaloric - isonitrogenous (2596 DE and 15% CP) with 3 different levels of dietary crude fiber (Table 1). Experimental diets were high fiber (HF, 19% contained 70 % alfalfa), moderate fiber (MF, 15% contained 40 % alfalfa), which was considered as a control diet and low fiber (LF, 11% contained 20 % alfalfa). The alfalfa included in the experimental diet was sun-dried. All animals were fed ad libitum and have free excess to fresh water.

Table 1. Diet composition

	g/ 100 diet		
Ingredients	Control (15%)	LF (11%)	HF (19%)
Alfa-alfa	40.0	20.0	70.0
Barley	44.6	50.0	3.75
Soybean	4.0	10.0	1.3
Yellow corn	-	-	13.8
Wheat bran	10.0	10.0	8.0
Rice straw	0.6	8.6	1.3
Bone meal	-	.70	-
Salt	0.2	0.2	0.2
Premix [1]	0.1	0.1	0.1
DL- methionine	0.3	0.3	0.3
Sod. Phosphate	0.2	-	0.5
Corn oil	-	-	0.75
Chemical analysis			
Crude fiber, %	15.5	11.3	19.2
Crude protein, %	15.0	15.2	15.3
Ether extract, %	1.5	1.4	2.3
Calculated energy (Kcal, DE/kg)	2644	2598	2596
C/ P ratio	176	171	170

[1] Each package of 6 kg contains: 12 million IU Vit.A; 0.9 million Vit.D3; 2 g Vit.K 50 g Vit. E; 1.2 million mg Choline chloride; 50 g Nicotinic acid; 2 g Vit. B6; 200 mg Vit. B1; 6 g Vit. B2; 10 mg Vit. B12; 200 mg Biotin; 5 g Folic acid; 20 g Pantothenic Acid; 400 g Mg; 3 g Cu; 200 mg I; 100 mg Se; 75 g Fe; 30 g Mn; 70 g Zn; 100 mg Co

Performance

Body weights were recorded weekly and body weight gains were calculated, only during the first two months post weaning due to high mortality rate of LF group. Feed consumption was recorded daily and feed intake was calculated after subtraction of feed spillage from feed consumption for each individual. Feed conversion (FC) was calculated [FC = feed (g) / gain (g)].

Gastrointestinal tract and carcass cut up parts characteristics

Three animals were slaughtered weighing around of average body weight of each treatment at ages 3 and 5 months. The weights of head, trunk, forelimbs, hindlimbs and giblets as well as fur were recorded to the nearest (g) and expressed as absolute weight. Also, fresh tissues weight of stomach, intestine, cecum and colon were recorded. The physiological volume of stomach and cecum were measured as the volume of water when the organ, empty of contents, were sunk in a measuring cylinder and subtracted from the volume of water when the same organ was filled with its contents. The anatomical volume of the small intestine, cecum and colon were estimated mathematically according to the following formula: AV= Kr2, where; AV= anatomical volume, K= constant (22/7), r= radius, and L= length [the radius was calculated from the circumference (c) using the formula c= 2 cr]. Also, fresh tissue weight of stomach, intestine, cecum and colon were recorded as absolute weight.

Digestibility trial

At age of 5 months old, 5 rabbits were randomly chosen from each group and kept individually in metabolic cages to perform the digestibility trial. Feces were collected daily for 5 consecutive days, dried at 105°C for 24 hours. Feed consumption per rabbit was recorded daily for the same period. Chemical analyses of nutrients and digestibility were performed according to the A.O.A.C (1980). Total digestible nutrients were calculated according to McDonald *et al.* (1985) using the following formula:

% TDN= [% dig. crude protein (CP)+ % dig. nitrogen free extract (NFE)+ % dig. crude fiber (CF)+ 2.25 x % dig. ether extract (EE)]

Statistical analyses

Data were statistically analyzed using Harvey (1987) computer program. Significant differences among means were separated by Duncan's new multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Growth performance

Recorded data on rabbits performance, body weight, body gain, feed conversion and mortality (%) are summarized in (Table 2). Results indicated that rabbits body weights were slightly higher by 6.4% and 4 % in the LF fed group compared to MF and HF groups, respectively at10 week-old. However, at 14 week-old body weight of the same group of rabbits was decreased by 6.7 and 7 %, respectively, such decrease was not significant. Body gains for all groups were; 376, 379 and 455g for HF, MF and LF, respectively at 10 week-old on experimental diet. The percentage of body gain for the LF and HF to the control group was estimated to be 120% and 99%, respectively. While, results of body gain at 14 week-old were 451, 457 and 256g for HF, MF and LF groups, respectively. However, the percentage of body gain for the LF fed group seemed to be reduced to 56% during the second 4 weeks on experimental diet, while the HF fed group was the same 99% compared to the control group. The overall means of body gain showed no significant differences among dietary groups. It was speculated that rabbits received HF diet (70% alfalfa) or MF (40% alfalfa) with same C/P ratio (170) may adapt to the level of fiber after the first 4 weeks on the experimental diet. Hence, improved body weight would result regardless of fiber levels. Similar results were obtained in pigs by Varel and Yen (1997) who recommended 3 to 5 weeks before adapting to the digestibility of resistant non-starch polysaccharide monomers. Inclusion of alfalfa meal in rabbit' diet based on cereal was found to give maximum response in growth performance (Pote *et al.*, 1980). While, growth rate of fryer rabbits was reported to be decreased when fed low- fiber diet Champe and Maurice (1983), Cheek and Patton (1980), Pote *et al.* (1980) and Soliman *et al.* (1992).

Table 2. Effect of different dietary fiber levels on rabbits body weight, body gain, daily feed consumption, feed conversion, mortality and diet volume and density (g/cm3)

Parameters	Control (15% CF)	LF (11% CF)	HF (19% CF)
Initial body weight (g), 6-wk.	921 ± 51.11	928 ± 51.11	973 ± 51.11 [1]
Body weight (g), 10-wk. [2]	1300 ± 71.92	1383 ± 85.13	1331 ± 47.30
„ „ , 14-wk.	1757 ± 102.60	1639 ± 108.56	1764 ± 55.99
„ gain , 6-10 wk.	379	455 (120%[3])	376 (99%)
„ „ , 10-14 wk.	457	256 (56%)	451 (99%)
„ „ , 6-14 wk.	836	711 (85%)	827 (99%)
Daily feed intake, 6-10 wk.	88	81	88
„ „ „ , 10-14 wk.	119	110	110
„ „ „ , 6-14 wk.	104	92	99
Feed conversion, 6-10-wk.	6.48 ^{a}	4.97 ^{b}	6.52 ^{a}
„ „ , 10-14 wk.	7.34 ^{b}	11.25 ^{a}	6.83 ^{b}
„ „ , 6-14 wk.	6.95	7.23	6.69
Mortality (n= 15)	1 (6 %)	6 (40%)	- (0.0%)
Diet volume/ 100g	333.3	238.1	454.5
density (g/cm^3)	0.30	0.42	0.22

[1] Means with different superscripts (a,b and c) are significantly different ($p< .05$)
[2] Body weight at 4 or 8- weeks postweaning (10 or 14 week-old)
[3] Values are expressed as percentage of the control

Feed intake and feed conversion

Average daily feed intake appeared to be numerically lower in animals fed LF compared to those fed either HF or MF diets. Accordingly, energy intake was 239 compared to either 257 or 275 kcal DE per animal per day, respectively. Hence, feed conversion was significantly ($P<0.05$) improved in the same group only during the first 4-weeks period on experimental diet. On the contrary. Feed conversion was significantly ($P<.05$) lowered in LF compared to either, HF or MF fed groups during second 4-weeks on experimental diets. The high fiber diet was reported to increase feed intake in rabbits from weaning to the first kindling (Xiccato *et al.*, 1999). This may confirm the lower body weight found earlier in LF fed group during the second 4-weeks period on the experimental diet (Table 2). When comparing density of experimental diets, LF diet had the highest density (0.42g / cm3) of MF diet (0.30g /cm3) and HF diet (0.22g / cm3). Therefore, inclusion of alfalfa in rabbits diet at levels 70% and 40% resulted in diluting diet and nutrients concentration, hence, rabbits increased their feed intake as means of compensation. Lower feed consumption in rabbits fed low- fiber diet was explained by (Laplace, 1978; and Fraga *et.al.*, 1991) due to prolonged retention time of feed in the GIT and cecal parts. In this study continuos feeding of concentrate diet (diet density was .42g/cm3) with LF resulted in disorders in the GIT and frequent diarrhea, hence lowered feed conversion compared to MF (density was .30g/cm3) or HF diet (density was .22g/cm3). These results are in agreement with findings reported by Anber (1986) in Bouscat rabbits, Carregal (1978) and Khashaba (1988) in New Zealand rabbits and Radwan and Allam (1979) in Baladi Red rabbits.

Mortality

Mortality percentage of LF fed group was higher (40%) than that of MF (6%) or HF (0%) groups. Diagnostic symptoms observed with LF fed group were characterized by a decrease in live body weight during second 4-weeks of the trial; decreased in feed intake, diarrhea, weakness then death were observed. Similar findings were reported by Bombeke, (1978) and de Blas *et al.* (1986).

Nutrients digestibility

The digestibility coefficient of nutrients, total digestible nutrients (TDN) and albumin ratio are listed in (Table 3). The results indicated that as percentage of crude fiber increased in the diet, the digestibility coefficient of OM and NFE were decreased ($p< .05$) significantly. Decreasing percentage of NFE would result in lower energy content of HF diet and hence, affecting rabbits performance. Moreover, the TDN values and Albumen ratio were significantly ($p< .05$) decreased in HF fed group. It appears that the rabbits were not able to utilize energy from the fiber fraction of the high- fiber diet. These results are in agreement with those reported by Grobner (1985); Soliman *et al.* (1992), Zeweil (1992); de Blas *et al.*, (1995) and Fernandez *et al.*, (1998). Therefore, moderate level of crude fiber was most suitable, since it maintained the digestibility coefficient of nutrients and protected against enteritis.

Table 3. Effect of feeding rabbits different dietary fiber levels on digestibility coefficient (DC), total digestible nutrients (TDN) and albumin ratio

Item	Control (15% CF)	LF (11% CF)	HF (19% CF)
Organic matter	$68^{ab} \pm 2.96$	$72^{a} \pm 1.2$	$64^{b1} \pm 2.40$
Crude protein, (CP)	72 ± 2.08	76 ± 1.76	69 ± 4.41
Crude fiber, (CF)	40 ± 5.21	32 ± 2.31	40 ± 4.66
Ether extract, (EE)	$58^{b} \pm 1.53$	$72^{a} \pm 2.88$	$73^{a} \pm 2.00$
NFE	$79^{a} \pm 1.33$	$79^{a} \pm 1.53$	$72^{b} \pm 1.00$
TDN	$57.3^{b} \pm .87$	$61.1^{a} \pm 1.01$	$53.2^{c} \pm 2.03$
Albumin ratio [2]	$4.7^{a} \pm .47$	$4.0^{a} \pm .03$	$3.8^{b} \pm .13$

[1] Means with different superscripts (a,b and c) are significantly different ($P< .05$)
[2] Albumin ratio= dig. CP/ [dig. NFE + dig. CF + 2.25 x dig. EE]

Carcass characteristic.

The carcass cut- up parts and edible viscera values, at 3 and 5 months old, are summarized in Table 4. Most values tended to be higher in rabbits received MF diet than those received HF or LF diets, and more specifically at 5 month-old than at 3 month-old. It is so important to notice that the hindlimbs hold most of the muscle mass in the carcass and that decreasing its mass is explained by the lower values of both the TDN and Albumen ratio that was mentioned early. Irrespective of dietary HF effect on liver, trunk, hindlimbs, forlimbs and fur; no differences were found in other carcass parts. Similar results were reported by Afifi *et al.*, (1967); Abdella *et al.* (1987); Khashaba (1988) and Zeweil (1992).

Table 4. Weight of body components (g) of rabbits as influenced by dietary crude fiber at ages, 3 and 5 months

Crude fiber, %	Control (15% CF)		LF (11% CF)		HF (19% CF)		SE
Age (month)	3	5	3	5	3	5	
Head	118.00	181.33^{a}	130.0	165.3^{b}	116.33	161.50^{b}	5.78
Trunk	304.07	674.33^{a}	428.66	551.0^{b}	293.00	510.0^{b}	37.93
Forelimb	127.00	250.00^{ab}	188.6	200.0^{b}	140.67	349.5^{a}	50.31
Hindlimbs	286.67	547.00^{a}	362.67	426.67^{b}	266.0	294.5^{c}	29.86
Liver	61.67	81.00^{a}	57.33	67.67^{b}	46.0	57.5^{b}	6.42
Lung	10.67	19.00	16.67	12.67	12.0	15.5	2.25
Heart	5.00	8.00	8.67	7.33	7.0	9.00	1.53
Spleen	1.33	1.33	2.0	1.0	2.0	2.25	0.68
Kidney	13.00	17.33	14.33	15.33	15.67	16.00	0.68
Skin	233.33	508.33^{a}	300.67	360.0^{b}	200.67	415.00^{a}	28.07

[1] Means with different superscripts (a,b and c) are significantly different (P< .05)

Gastro-intestinal tract (GIT) characteristics

Fresh weights of different parts of the gastrointestinal tract are presented in (Table 5). The average value of stomach weight at 5 month-old was higher (P<.05) in HF compared to either LF or MF fed animals. Also, cecum and total weight of GIT were slightly higher but not significant. The physiological volume of stomach and cecum were not influenced by levels of crude fiber, with the exception of animals received LF diet at 5 month-old. Where stomach volume of LF fed rabbits was decreased significantly (P<.05) by 37 and 21% compared to HF and MF fed rabbits, respectively (Table 5). The inclusion of concentrates into roughage-based rations of calves, goats and domestic buffalo retards the development of stomach size and musculature (Lyford, 1988). Similar results were obtained in goats and sheep by Kobeisy (1990).

The anatomical volume, length and circumference of the intestinal segments are listed in Table, 6. No differences were found due to dietary crude fiber levels in any of the parameters mentioned above. However, cecum length was increased in rabbits fed LF diet at both ages, 3 and 5 months (p<.05). Also, the anatomical volumes tended to be higher in LF fed group, mostly due to the increase of cecum volume. These results may be attributed to the retention time of high concentrate diet and fermentation in cecum part, which consequently increased production of VFA's. Sakata *et al.* (1980) found that the mitotic index in crypts of proximal and distal colon was significantly increased within 1 hr. of injection of the VFA's solution.

Table 6. Length, circumference and anatomical volume of different parts of intestinal segments in rabbits as influenced by dietary crude fiber at different ages

Crude fiber, %	Control (15% CF)		LF (11% CF)		HF (19% CF)		SE
Age	3	5	3	5	3	5	
Length, cm							
Small intestine	270.00	293.33	285.00	271.67	250.67	260.67	21.28
Cecum	44.67	48.33^{ab}	49.67	51.67^{a}	44.00	44.00^{b}	2.36
Colon	96.00	107.67	111.67	104.67	99.67	95.33	7.27
Circumference, cm							
Small intestine	1.66	1.60	1.86	1.51	1.80	1.66	0.12
Cecum	4.92	4.05	4.87	4.68	4.96	4.32	0.22
Colon	2.10	1.77	2.32	1.99	2.33	1.89	0.22
Anatomical volume							
Small intestine	61.0	60.33	80.00	56.02	66.33	59.00	11.82
Cecum	86.67	63.33	93.33	80.00	80.00	65.67	9.46
Colon	34.67	27.00	49.00	39.00	50.33	27.00	11.28
Total	392.33	328.00	454.33	374.00	438.88	340.33	47.08

[1] Means with different superscripts (a,b and c) are significantly different (p< .05)

Table 5. Fresh tissue weight (g) of the different parts of the gastrointestinal tract and physiological volume (ml) of stomach and cecum in rabbits fed different levels of dietary crude fiber

	Fresh tissue weight (g)						Percentage of change				
Crude fiber, %	Control (15%)		LF (11%)		HF(19%)		LF (11%)		HF(19%)		SE
Age, month	3	5	3	5	3	5	3	5	3	5	
Fresh tissue weight							%	%	%	%	
Stomach	33.67	35.67^{b}	35.67	33.00^{b}	35.33	59.00^{a}	+5.9	-7.5	+4.9	+65.4	8.03
Intestine	44.33	58.00	56.67	60.33	50.33	52.00	+27.8	+4.5	+13.5	-10.3	4.90
Cecum	34.33	57.67	46.67	49.33	37.00	71.33	+35.9	-14.5	+7.8	+23.7	10.36
Colon	29.67	31.67	38.00	29.67	26.33	33.00	+28.1	-6.3	-11.5	+4.2	2.92
Total	142.00	183.00	177.00	172.33	149.00	215.33	+24.6	-5.8	+4.9	+17.7	19.69
Physiological volume, (ml)											
Stomach	76.00	70.00^{ab}	91.67	55.00^{b}	75.00	86.67^{a}					10.10
Cecum	75.00	98.33	91.67	81.67	76.67	83.33					15.21

[1] Means with different superscripts (a,b and c) are significantly different (p< .05)

[2] Values are expressed as percentage (+ or -) of the control.

In conclusion, low fiber diet may be used in rabbits, particularly from weaning up to 10 weeks old, after that high fiber is suggested to avoid the adverse effects of low fiber diet on rabbits' GIT characteristics and performance.

These results indicated that characteristics and development of the GIT was influenced by dietary treatment as much as digestibility coefficient of nutrients. Also, dietary fiber manipulation to rabbits is suggested after 4- week post weaning to regulate GIT motility and avoid mortality due to enteritis.

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