ALTERNATIVE FEEDS FOR THE GROWING RABBIT: CARROT ROOTS. EFFECT ON PERFORMANCE AND DIGESTION

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ABSTRACT

The objective of this study was to evaluate the effect of including carrot roots in rabbit diets with normal and bellow-recommended neutral detergent fibre (NDF) values. Four isoproteic diets were formulated according to a 2x2 factorial arrangement: two NDF levels (37% and 30% on a DM basis) and two levels of dry carrot roots (0 or 15%). Diets were fed *ad libitum* to 4 x 12 weaned rabbits (22 days old) for 6 weeks. Growth performance, feed digestibility (during the 5th week), fermentative activity at day 35 on caecotrophes and small intestinal morphology were determined. Carrot inclusion did not influence daily feed intake or daily weight gain, neither immediately post-weaning nor between 35-63 days. However, it worsened feed conversion ratio (10%). Reducing fibre content led to reduced feed intake (17 and 19%, 1st and 2nd period) and better conversion ratios (9 and 16%, in 1st and 2nd period). Dry matter, organic matter (OM), energy and crude protein (CP) digestibility were not affected by carrot inclusion. Contrarily, ADF and cellulose digestibility of diets with carrots was about 45% and 65% higher than those without carrots. At 35 days, volatile fatty acids (VFA) from caecotrophes of rabbits fed with carrots had significantly higher values for C2 and lower for C4 ($P<0.05$). Fibre had significant ($P<0.05$) effects on villus height, crypt depth and villus height/crypt depth.

Keywords: Carrot roots, Digestibility, Intestinal morphology

INTRODUCTION

Carrot (*Daucus carota L.*) is widely used in human feeding. It has health-promoting properties due to the high presence of carotenoids and dietary fibre. Indeed, various studies within human nutrition indicate that beta-carotenes have antioxidant properties and its soluble fibre benefit the gastrointestinal tract (Sharma *et al*., 2012). Moreover, its high content of provitamin A contributes to maintain and regulate the immune system (Veldhoen and Brucklacher-Waldert, 2013). The root of this plant is frequently rejected during its production chain, which makes it suitable to be used for animal nutrition.

During the post-weaning period, rabbits are particularly vulnerable to digestive problems. To minimize their repercussions, different strategies have been proposed, among them the dietary inclusion of soluble fibre that can help fixate beneficial microflora that improves the competition against pathogens (De Blas, 2012). In addition, the improved immune response and feed efficiency has been reported elsewhere with the inclusion of soluble fibre in post-weaning rabbit diets (Gomez-Conde *et al*., 2007).

The objective of this study was to evaluate the protective effect of carrot roots on the digestive system of early-weaned rabbits. For this purpose, the effects of dietary fibre contents (recommended and low values) were compared in diets with and without carrot roots, during the whole growing period. The following parameters were analysed: growth performance, feed digestibility, caecotrophes fermentative activity and small intestine morphology.

MATERIALS AND METHODS

Animals and experimental design

Four isoproteic diets were formulated according a 2x2 factorial arrangement: 2 NDF levels (37% and 30% on a DM basis) and 2 levels of carrots (0 or 15%) (Table 1). The carrot roots were cut and dried at 40ºC before being milled and included in the feed. These pelleted diets were provided *ad libitum* for

6 weeks. Each group consisted of 12 individually housed rabbits balanced for live weight, weaned at 22 days old. Rabbits were weighed each week and feed intake was measured three days per week. During the fifth week of trial, faeces were collected to calculate the total tract apparent digestibility. At 35 days of age, light plastic collars were placed around their necks at 08:30 hours and taken out after 2 samples of 3-4 g of caecotrophes had been harvested. The caecotrophes were placed into plastic bottles for DM and VFA analyses. For VFA analyses, the caecotrophes were stored in a bottle with 4 mL of a 0.03 M H3PO4. At slaughter, one section was taken from the ileum for histological analysis of the mucosa, as reported by Ribeiro *et al.*, (2012).

Table 1: Ingredients (% as fed basis) and nutritional composition (on a DM basis) of the experimental diets.

	37% NDF		30% NDF			37% NDF		30% NDF	
	0 % carrots	15 % carrots	0 % carrots	15 % carrots		0 % carrots	15 % carrots	0 % carrots	15 % carrots
Ingredients					Chemical composition (% dry matter)				
Carrot roots[1]	0	15.0	0	15.0	Dry matter	92.6	92.7	92.7	91.9
Wheat	15.0	0	36.5	16.5	Organic matter	92.4	91.4	93.7	92.9
Barley	15.0	10.0	15.0	15.0	Crude protein	17.3	17.1	17.4	17.3
Soybean meal	10.0	12.5	9.0	11.5	NDF	37.0	38.8	29.5	30.9
Sunflower meal 28	12.0	12.0	12.0	12.0	ADF	21.2	23.6	16.2	18.2
Dehydrated alfalfa	30.0	32.5	17.0	19.5	ADL	4.9	4.3	3.7	3.8
Wheat straw	15.0	15.0	7.5	7.5	Hemicellulose	15.8	15.3	13.5	12.7
Vegetal oil	2.0	2.0	1.5	1.6	Cellulose	16.3	19.3	12.5	14.4
DL-methionine	0.04	0.08	0.02	0.06	Gross Energy (kcal/kg DM)	4405	4354	4363	4346
L-lysine	0.11	0.09	0.18	0.14					
ClNa, $CaHPO_4$ CaCO3, premix[2]	0.85	0.83	1.3	1.2					

[1]carrot roots (% on DM basis): CP = 5,6%; NDF= 11.4%; ADF=7.6%.
[2]Premix provided per kg of complete diet: vitamin A, 1000 UI; vitamin D3, 1500 UI; vitamin E, 15 mg; vitamin K3, 1.5 mg; vitamin B1, 1 mg; vitamin B2, 2 mg; vitamin B6, 1.5 mg; vitamin B12, 0.01 mg; pantothenic acid, 8 mg; nicotinic acid, 25 mg; biotin, 0.02 mg; betaine, 136.5 mg; robenidine, 50 mg; Co, 0.7 mg; Cu, 5 mg; Fe, 30 mg; I, 1 mg; Mn, 15 mg; Se, 0.2 mg; Zn, 30 mg; ethoxyquin 12.5 mg; butylated hydroxytoluene 12.5 mg.

Chemical Analyses

Dry matter, OM, CP, NDF, acid detergent fibre (ADF), acid detergent lignin (ADL) and gross energy of feed and faeces were determined according to the procedures proposed by EGRAN (2001). Volatile fatty acid analysis was carried out for the caecotrophes using gas chromatography. Microscopic examination and villi measurements were performed as previously reported by Ribeiro *et al* (2012).

Statistical Analysis

Data concerning growing performance, total tract apparent digestibility, fermentative activity parameters and intestinal morphology were compared by two-way analysis of variance according a 2X2 factorial arrangement, considering NDF level, carrot inclusion and their interaction. All statistical analysis were performed using the SAS system.

RESULTS AND DISCUSSION

Neither carrot inclusion nor the reduction of NDF level affected live weight during all experimental periods (Table 2). Average daily gain (ADG) and daily feed intake (DFI) were not affected by carrot inclusion in any period. When combined with 37% NDF, carrot inclusion had a negative impact on feed conversion ratio during both periods (9% and 11%, respectively). There was an interaction in the post-weaning period, however, feed efficiency was the same with and without carrot at lower NDF level.

Replacing wheat with carrot corresponded to a lower starch content and increase in soluble fibre and sugars, which could justify the higher feed conversion ratio. The negative effects on DFI and ADG, and the poorest feed efficiency could be associated with an increase in fibre content, as classically described in the literature (Gidenne *et al.*, 2017).

Table 2: Effect of dietary fibre level and carrot inclusion on the performance of growing rabbits.

	37% NDF		30% NDF		RMSE[2]	Statistical significance[1]		
	0% carrots	15% carrots	0% carrots	15% carrots		carrots	fibre	Carrots x fibre
Nb initial rabbits	12	12	12	12				
Nb final of rabbits	11	11	10	9				
Live weight (g)								
At 21 d of age	399	394	398	392	34.1	0.601	0.892	0.993
At 35 d of age	925[a]	817[ab]	779[b]	870[ab]	122	0.835	0.232	0.013
At 63 d of age	2408	2251	2255	2180	246	0.141	0.156	0.601
1st period (21-35 days of age)								
Daily feed intake (g)	60.3	57.1	46.6	51.2	12.6	0.857	0.016	0.319
Average daily gain (g)	39.9	32.7	32.1	34.9	9.09	0.440	0.320	0.085
Feed conversion ratio	1.51[b]	1.78[a]	1.49[b]	1.49[b]	0.19	0.037	0.018	0.043
2nd period (35-63 d of age)								
Daily feed intake (g)	143	148	115	121	19.1	0.313	<0.001	0.952
Average daily gain (g)	52.9	51.2	52.7	49.3	6.32	0.201	0.600	0.670
Feed conversion ratio	2.69	2.89	2.17	2.51	0.21	<0.001	<0.001	0.410

[1]Means with different letters on the same row differ significantly; [2]RMSE: root mean square error.

Carrot dietary inclusion did not affect digestibility of DM, OM, energy or CP (Table 3). Considering the fibrous fractions, only ADF and cellulose digestibility were positively affected. Increased ADF digestibility occurs due to increased cellulose digestibility. In fact, the latter increased more than 60% compared to diets without carrot (26% *vs.* 15.8 %).

Table 3: Effect of fibre level and inclusion or not of carrot roots on diet on total tract apparent digestibility.

Coefficients of total tract apparent digestibility, %	37% NDF		30% NDF		RMSE[1]	Statistical significance		
	0% carrots	15% carrots	0% carrots	15% carrots		carrots	fibre	Carrots x fibre
Dry matter	61.3	60.9	71.4	70.4	2.90	0.444	<0.001	0.689
Organic matter	58.1	57.3	69.5	68.1	3.15	0.261	<0.001	0.777
Crude protein	79.3	79.2	83.2	81.4	2.94	0.311	0.002	0.358
NDF	22.0	26.1	27.4	28.7	6.19	0.165	0.046	0.478
ADF	13.9	21.9	19.5	26.9	6.13	<0.001	0.013	0.879
Hemicellulose (NDF-ADF)	32.9	32.6	36.8	31.2	7.46	0.206	0.588	0.261
Cellulose (ADF-ADL)	11.8	24.1	19.7	27.9	6.63	<0.001	0.007	0.325
Energy	59.8	58.7	69.5	68.3	3.11	0.247	<0.001	0.982

[1]RMSE: root mean square error.

Diets with low NDF level exhibited higher digestibility values for all fractions, except for hemicellulose. This effect originates in the reduction of undigestible fibrous material and organic matter, which results from the replacement of alfalfa with wheat or by both wheat and carrot in 0% and 15% carrot diets, respectively. Additionally, it is possible that a lower feed intake and a slower digesta passage rate allowed more time for endogenous and microbial enzymes to act upon the digesta, also contributing for increased digestibility in low NDF diets.

Two weeks after weaning, the soft faeces (representative of the caecal contents) of the rabbits fed with carrot roots had higher percentage of acetic acid (+ 3.8%) but lower (-22%) butyric acid (Table 4), which is nevertheless within the limits considered favourable to healthy gut health (Gidenne *et al.*, 2010). The level of dietary fibre had no effect on caecotrophes VFA profile.

Table 4: Effect of fibre level and inclusion of carrot roots on fermentation parameters of caecotrophes

	37% NDF		30% NDF		RMSE[1]	Statistical significance		
	0% carrots	15% carrots	0% carrots	15% carrots		carrots	fibre	Carrots x fibre
Caecotrophes								
DM (%)	29.7	29.0	31.6	29.8	2.89	0.211	0.214	0.614
Total VFA (mmol/L)	33.4	29.9	35.8	31.0	11.2	0.294	0.651	0.865
C2 (mol/100 mol)	80.0	81.7	77.5	81.6	3.09	0.012	0.253	0.282
C3 (mol/100 mol)	7.3	7.5	7.5	7.6	1.03	0.222	0.445	0.996
C4 (mol/100 mol)	12.7	10.8	15.0	10.8	3.19	0.010	0.336	0.311

[1]RMSE: root mean square error.

The ileum mucosa was significantly affected by carrot inclusion and by fibre level. An interaction was detected in villus height (Table 5), where recommended dietary fibre leads to lower villus when combined with carrot root. In the case of crypt depth, the inverse occurred. Interestingly, the villus height/crypt depth ratio was higher in rabbits fed with lower NDF and was always negatively influenced by carrot inclusion.

Table 5: Effect of fibre level and inclusion of carrot roots on the morphology of the ileum mucosa.

	37% NDF		**30% NDF**			**Statistical significance[1]**		
	0% carrots	**15% carrots**	**0% carrots**	**15% carrots**	**RMSE[2]**	**carrots**	**fibre**	**Carrots x fibre**
Villus height (µm)	896[b]	822[b]	1239[a]	776[b]	189.0	<0.001	0.020	0.003
Crypt depth (µm)	123[b]	176[a]	116[b]	117[b]	32.6	0.014	0.004	0.018
Villus height/crypt depth	8.0	5.1	11.3	7.2	2.5	<0.001	0.002	0.451

[1]Means with different letters on the same row differ significantly; [2]RMSE: root mean square error.

CONCLUSIONS

In the experimental conditions described, wheat replacement by carrot roots, although unaffecting the global digestion, led to a worse feed efficiency. Dietary carrot inclusion seemed to favourably influence fermentation conditions in the caecum, particularly in the post-weaning period.

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