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ABSTRACT - To evaluate the effect of digestible fibre (DF) to starch ratio (0.8, 1.5, and 2.8) and protein level (15% and 16%) on health status, digestive physiology, growth performance, and carcass traits, 246 rabbits weaned at 33 d were fed until slaughter (75 d) six diets formulated according to a bi-factorial arrangement (3 DF to starch ratios by 2 protein levels). Growth performance and carcass quality at slaughter were not affected by treatments. Increasing DF to starch ratio did not modify dry matter digestibility (62.0% on average), while increased (P<0.001) DF digestibility (52.3 to 68.1%), stimulated caecal fermentation (total VFA: 56.0 *vs* 67.8 and 67.2 mmol/l; P=0.02) and changed VFA molar proportions. Increasing dietary protein increased digestibility of dry matter (P=0.02), crude protein (P<0.001) and digestible fibre (P<0.001) and increased caecal VFA production (P<0.01). The highest mortality (17.1% *vs* 1.5% average mortality of the other groups, P<0.001) was found in rabbits fed the diet with the lowest DF to starch ratio and the highest protein level.

Key words: Rabbits, Digestible fibre, Protein, Health status.

Introduction – Since the diffusion of epizootic rabbit enteropathy (ERE), research in rabbit nutrition has been oriented to define feeding strategies capable of preventing the occurrence of the disease or, at least, limiting the mortality (Gidenne and García, 2006). The role of dietary fibre and starch has been widely investigated and a protective effect of low-digested fibre fractions (cellulose and lignin) on gut health is recognized. Recently, a positive effect of the high-digestible fibre (DF=hemicelluloses and pectins) has also been proved: digestive troubles decreased when DF replaced starch in iso-ADF diets (Perez *et al.*, 2000; Soler *et al.*, 2004; Xiccato *et al.*, 2008) or when DF to ADF ratio increased (Xiccato *et al.*, 2006; Gómez-Conde *et al.*, 2007). Also high dietary protein may favour the development of some pathogenic bacteria, like *E. coli* and *Clostridia*, because of the increased nitrogen flow in the caecum (Carabaño *et al.*, 2008). The present study aimed to evaluate whether the DF to starch ratio and the protein level in diets for growing rabbits could affect digestive efficiency, growth performance, health status, and meat quality.

Material and methods – Two hundred and forty-six Grimaud rabbits weaned at 33 d were put in individual cages and fed six diets according to a bi-factorial arrangement with three DF to starch ratios (diets L=0.8, M=1.3 and H=2.8) and two crude protein levels (15 and 16%) (Table 1). The ADF level was higher than recommendations. No antibiotic was given in feed or water. Individual live weight and feed intake were recorded three times a week. Nine rabbits died during the trial, six of which fed diet L16. At 52 d a digestibility trial on 60 rabbits (10 per diet) was performed. At 55 d 36 rabbits (6 per diet) were sacrificed to sample caecal content. At 75 d the 201 remaining rabbits were slaughtered. Diet digestibility, chemical composition of diets, faeces and caecal content, and carcass traits were determined as described by Xiccato *et al*. (2003). Digestible fibre was calculated as the difference between total dietary fibre (TDF), determined by AOAC gravimetric/enzymatic procedure, and ADF. Growth performance and carcass traits were analysed by two-way ANOVA using the GLM procedure of SAS. The interaction starch to ADF ratio by protein level was not significant. Mortality and morbidity were controlled daily and analysed by the CATMOD of SAS.

Table 1. Ingredients, chemical composition and nutritive value of experimental diets.

	Diet L15	Diet M15[1]	Diet H15	Diet L16	Diet M16[1]	Diet H16
Ingredients (%):						
Alfalfa meal 17% CP	37.0	29.0	21.0	26.0	17.5	9.0
Wheat bran	10.0	18.3	26.6	3.5	11.4	19.4
Barley meal	34.3	19.6	5.0	37.8	23.4	9.0
Dried beet pulp	4.0	17.5	31.0	4.0	17.5	31.0
Sunflower meal 30% CP	10.0	5.0	0.0	19.0	14.5	10.0
Sunflower meal 36% CP	0.0	6.0	12.0	5.0	11.0	17.0
Minor ingredients and premix	4.7	4.6	4.4	4.7	4.7	4.6
Chemical composition (as-fed basis):						
Dry matter, %	90.3	89.9	89.8	90.3	89.6	89.3
Crude protein, %	15.0	15.2	15.5	16.0	16.3	16.3
TDF, %	37.4	40.6	44.8	35.7	41.0	48.5
NDF, %	33.1	34.8	35.7	32.9	34.0	36.8
ADF, %	19.3	20.1	20.5	19.4	19.7	21.8
ADL, %	4.4	4.1	4.1	4.7	4.6	4.8
DF (TDF-ADF), %	18.0	20.5	24.2	16.3	21.2	26.7
Starch, %	21.5	16.3	9.3	20.2	15.8	8.8
DF to starch ratio	0.8	1.3	2.6	0.8	1.3	3.0
Digestible energy (DE), MJ/kg	10.3	10.4	10.4	10.5	10.5	10.5
Digestible protein to DE ratio, g/MJ	10.5	10.5	10.6	11.1	11.2	11.2

[1]*Diet M15=50% Diet L15+50% Diet H15;*
Diet M16=50% Diet L16+50% Diet H16.

Results and conclusions – Increasing DF to starch ratio did not modify dry matter (62.0% on average), CP (71.9%) and gross energy (62.6%) digestibility, while increased (P<0.001) the digestive utilization of both ADF (from 16.7 to 27.1%) and DF (from 52.3 to 68.1%), as also found by others (Gidenne and Perez, 2000; Xiccato *et al.*, 2008). Increasing dietary protein increased digestibility of dry matter (61.4 *vs* 62.6%; P=0.02), crude protein (71.4 *vs* 72.5%; P<0.001) and digestible fibre (59.1 *vs* 62.1%; P<0.001) which could be related to the lower inclusion rate of alfalfa meal in the diets with 16% CP. Growth performance were not affected by diets (Table 2), confirming that DF can replace efficiently starch as energy source in rabbit feeding (Perez *et al.*, 2000; Xiccato *et al.*, 2008). Differently, mortality decreased with DF to starch ratio higher than 0.8 (P=0.04). Comparing the six diets, the highest mortality rate was found in rabbits fed diet L16 (17.1% *vs* 1.5% average mortality of the other groups, P<0.001). This result confirms the beneficial effect of increasing DF in high protein diets (Xiccato *et al.*, 2006; Carabaño *et al.*, 2008).

Increasing DF to starch ratio above 0.8 stimulated (P=0.02) caecal fermentation as proved by total VFA levels (56.0 mmol/l in group L *vs* 67.8 and 67.2 mmol/l in groups M and H; P=0.02) (Table 3). Moreover, acetate molar proportion raised (P=0.02), while butyrate and valerate proportions decreased (P≤0.05), to be ascribed to a lower starch flow into the caecum and a reduced amylolitic flora activity. Diets with 17% CP stimulated VFA production (P<0.01), likely because of a higher N availability for microbial growth, but did not modify VFA profile and ammonia concentration. At final slaughter, gut incidence increased (from 17.6 to 18.3 and 18.4% slaughter weight, P<0.01) with DF to starch ratio from 0.8 to 1.3 and 2.8. Previous studies showed that high beet pulp inclusion levels increased digestive retention time and gut incidence (Gidenne and Perez, 2000). Dressing percentage and meat pH and colour were similar among treatments (data not reported).

In conclusion, increasing DF to starch ratio did not affect productive traits, since digestible fibre replaced starch as an energy source, and modified fermentation activity. Increasing dietary protein from 15 to 16% did not change growth performance or slaughter results since nitrogen requirements were satisfied also at the lowest concentration. Differently, an increased mortality rate was detected when high dietary protein level was associated to DF to starch ratio lower than 1.

Table 2. Growth performance and health status.

	DF to starch ratio				Protein level			RSD
	L=0.8	M=1.3	H=2.8	Prob.	15%	16%	Prob.	
Rabbits, no.	63	69	69		103	98		
Live weight at 33d, g	827	830	829	0.94	828	830	0.84	56
Live weight at 75d, g	2731	2779	2745	0.60	2746	2760	0.71	265
Daily gain, g/d	45.4	46.4	45.6	0.60	45.7	46.0	0.72	5.9
Feed intake, g/d	143	147	144	0.38	145	145	0.95	18
Conversion index	3.16	3.19	3.17	0.82	3.18	3.16	0.61	0.25
Mortality[1], %	10.0[b]	1.4[a]	1.4[a]	0.04	1.9	6.7	0.10	
Morbidity, %	2.9	8.4	5.8	0.39	4.8	6.7	0.56	

[1]Mortality: 17.1 vs 2.9, 0, 2.9, 2.9 and 0% for diets L16 vs L15, M15, H15, M16 and H16 (P<0.001). [a, b] P<0.05.

Table 3. Caecal fermentation activity at 55 d of age.

	DF to starch ratio				Protein level			RSD
	L=0.8	M=1.3	H=2.8	Prob.	15%	16%	Prob.	
Rabbits, no.	12	12	12		18	18		
pH	5.96	5.75	5.95	0.12	5.91	5.87	0.60	0.27
N-NH_3, mmol/l	9.1	6.9	6.2	0.18	7.2	7.6	0.72	3.8
Total VFA, mmol/l	56.0[a]	67.8[b]	67.2[b]	0.02	59.0	68.4	0.01	10.3
C2 (% molar VFA)	80.4[a]	81.1[ab]	83.3[b]	0.02	81.7	81.6	0.97	2.5
C3 (% molar VFA)	4.9	4.2	4.5	0.44	4.7	4.3	0.36	1.3
C4 (% molar VFA)	13.9[b]	14.1[b]	11.7[a]	0.05	13.0	13.5	0.59	2.5
C5 (% molar VFA)	0.8[B]	0.6[AB]	0.5[A]	<0.01	0.6	0.6	0.30	0.2

[a, b]P<0.05; [A, B]P<0.01.

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