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Original article

Effect of protein source on digestion and growth performance of early-weaned rabbits

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Abstract — Four diets based on different vegetal protein concentrates: soya bean meal 48 (SB48 diet), soya bean protein concentrate (SB61 diet), sunflower meal 36 (SF36 diet) and a combination of soya bean meal 48 and potato protein concentrate (SB48-P77 diet) were formulated for the starter period (25–39 days) in early weaned rabbits (25 days of age). These sources of protein accounted for 30% of the total dietary crude protein (CP) content. All diets were formulated to be isonutritive and to meet or exceed all the essential nutrient requirements of growing rabbits. A feeding trial was conducted to measure the effect of the treatments on growth performance in 204 rabbits that were fed ad libitum the experimental diets in the starter period and thereafter received a common feed until 60 d of age. Faecal and ileal apparent digestibility of dry matter (DM) and CP (9 and 7 replicates, respectively) were determined at 35 d of age. The weights and pH of the stomach and caecal contents, ammonia concentration in the caecum and jejunal morphology were also determined (11 rabbits per diet). The treatments did not affect faecal DM and CP digestibility. However, the source of protein affected ileal digestibilities of DM and CP ($P < 0.04$), which were around 14 and 7% higher for SB61 and SF36 diets, respectively, than for the SB48 diet, whereas the values obtained for the SB48-P77 diet were intermediate. The ileal flux of CP and the N-NH_3 caecal concentration were ($P = 0.08$ and 0.05, respectively) affected by the source of protein. The highest values were observed in animals fed the SB48-P77 diet, increasing by around 25 and 35%, respectively, compared to the other three diets. The treatments had no effect on digestive traits and jejunal morphology. The differences in ileal digestion efficacy among treatments led to differences ($P = 0.008$) in food efficiency the first week after weaning, which was higher (10%, as average) in animals fed the SB61 diet than that observed for animals fed the SB48 and SB48-P77 diets, whereas the value obtained for SF36 was intermediate. In this period, the type of diet tended ($P = 0.08$) to affect daily gain and food efficiency, with the lowest values obtained for the SB48 diet. The treatments had no effect on mortality in the first two weeks after weaning. However, mortality in the whole fattening period was affected by protein source ($P = 0.03$), since it was higher in animals fed the SB48-P77 diet after weaning than the animals fed the other three diets (34.6 vs. 16.7%, respectively). In conclusion, SF36 and SB61 are the sources of protein that led

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to the best growth performances and the lowest mortality rate. The higher efficiency obtained for these feeds might be mainly related to its higher ileal (CP) digestibility.

sources of protein / digestion / growth performance / early weaning / rabbits

Résumé — Effet de la source protéique sur la digestion et la croissance de lapereaux sevrés précocement. Quatre aliments à base de concentrés protéiques d'origine végétale ont été formulés pour la période de démarrage (25–39 j) de lapereaux sevrés précocement (25 j d'âge). Les concentrés protéiques, qui fournissaient 30 % des matières azotées totales (MAT), ont été : une farine de soja 48 (aliment SB48), un concentré de protéine de soja (aliment SB61), une farine de tournesol (aliment SF36) et une combinaison de farine de soja 48 et de concentré protéique de pomme de terre (aliment SB48-P77). Tous les régimes ont été formulés pour que la concentration des principaux éléments nutritifs soit identique, et ont satisfait ou dépassé les besoins des lapins en croissance. Un essai d'alimentation a été conduit pour mesurer l'effet des traitements sur la croissance de 204 lapins nourris à volonté pendant la période de démarrage jusqu'à l'âge de 60 jours, avec un aliment commun. Les valeurs de digestibilité apparente fécale et iléale de la matière sèche (MS) et des MAT (9 et 7 répétitions, respectivement) ont été mesurées à 35 j d'âge. De même, le poids et le pH du contenu de l'estomac et du caecum, la teneur en ammoniac de ce dernier et la morphologie du jéjunum ont été déterminés (11 lapins par aliment). Les traitements n'ont pas eu d'effet significatif sur la digestibilité fécale de la MS et des MAT. En revanche, la source protéique a eu un effet significatif ($P < 0{,}04$) sur la digestibilité iléale de ces paramètres, qui a été supérieure de 14 et de 7 %, respectivement, avec les aliments SB61 et SF36 par rapport à l'aliment SB48, alors que les valeurs obtenues avec l'aliment SB48-P77 ont été intermédiaires. Le flux iléal de MAT et la teneur en N-NH_3 du caecum ont également été affectés par la source de protéique ($P = 0{,}08$ et 0,05, respectivement). Les valeurs maximales ont été observées pour le traitement SB48-P77, qui ont été en moyenne de 25 à 35 % supérieures à celles des trois autres aliments. Les traitements n'ont pas eu d'effet sur les paramètres du contenu digestif et la morphologie du jéjunum. Les différences entre aliments, au niveau de la digestibilité iléale, ont conduit à des différences ($P = 0{,}008$) dans l'efficacité alimentaire, la première semaine suivant le sevrage. Celle-ci a augmenté de 10 % pour l'aliment SB61 par rapport à SB48 et SB48-P77, alors que l'aliment SF36 a produit des valeurs intermédiaires. Durant cette la période, l'aliment a eu tendance à modifier ($P = 0{,}08$) la croissance journalière ou l'ingestion d'aliment, avec des valeurs minimales pour l'aliment SB48. Les traitements n'ont pas eu d'effet sur la mortalité, les deux semaines suivant le sevrage. En revanche, pendant toute la période d'engraissement, elle a été affectée par la source protéique ($P = 0{,}03$), avec une mortalité supérieure pour les animaux du lot SB48-P77 (34,6 vs. 16,7 %). En conclusion, les meilleures performances de croissance et la moindre mortalité ont été observées avec les aliments SF36 et SB61. Ces résultats sont à relier, principalement, à la digestibilité iléale des MAT élevée.

sources de protéine / digestion / croissance / sevrage précoce / lapin

1. INTRODUCTION

Early weaning has a potential interest for commercial farms, since it decreases the risks of neonatal infections [22], and reduces the energy deficit of rabbit does [25]. The digestive capability of young rabbits might, however, be insufficient, and might require the design of appropriate starter diets.

The type of protein is a major restraint in these kinds of feeds, since gastric acidity could be not enough to allow a maximal pepsin activity [3, 26]. Furthermore, gastric and pancreatic protease activities are lower in young than in adult animals [8] and could decrease protein ileal digestibility. An increase of protein ileal flux has been related to the proliferation of Clostridia and E. Coli in the hindgut [4, 16]. Furthermore, an increase of mortality was observed around the weaning period in rabbits fed diets containing a high proportion of soya bean meal with respect to diets based on animal protein [21]. In the same way, Gutiérrez et al. [13, 14] have observed a positive effect of the substitution of soya bean meal with animal plasma in starter diets for early weaned rabbits on intestinal morphology, intake and growth performance.

These results suggest that the influence of the type of protein on performance might be higher in young than in adult animals. In this context, the objective of this work was to compare traditional (soya bean and sunflower meal) with highly digestible (soya bean and potato protein concentrates) sources of protein in starter diets for early weaned rabbits.

2. MATERIALS AND METHODS

2.1. Diets

Four diets based on different vegetal protein concentrates were formulated: soya bean meal 48 (SB48 diet), soya bean protein concentrate (SB61 diet) (Soycomil P-economy®, Loders Croklaan, Wormerveer, Holland), sunflower meal 36 (SF36 diet) and a combination of soya bean meal 48 and potato protein concentrate (Protamyl PF®, AVEBE Corporate, Holland) (SB48-P77 diet). The level of inclusion of potato protein concentrate was limited because of its solanine content, which has been proven to impair piglet performance when it is included above 3% in the diet [19]. These sources of protein accounted for 30% of the total dietary crude protein content. The chemical composition of the protein concentrates is shown in Table I. The diets were formulated to be isonutritive and to meet or exceed the essential nutrient requirements of growing rabbits [6]. All the diets were supplemented with a mixture of 100 ppm of Zn-bacitracin and 60 ppm of apramycin sulphate, and 6.5 $g \cdot kg^{-1}$ of alfalfa hay marked with Yb_2O_3 following the procedures described by García et al. [10]. The diets were pelleted and animals were given ad libitum access to feed in all the trials. The ingredients and chemical composition of the diets are shown in Table II.

2.2. Animals and housing

All the experiments were carried out with New Zealand × Californian rabbits weaned at 25 d of age. No control of sex was done in any trial. The animals were housed

Table I. Chemical composition of protein concentrates ($g \cdot kg^{-1}$).

	SB48	SB61	SF36	P77
Dry matter	877	905	908	904
Ash	60	62	80	20
Crude protein	466	669	360	775
Lysine[1]	30.3	43.5	12.6	59.3
Methionine[1]	6.5	9.4	8.3	17.6
Methionine + cystine[1]	13.5	19.4	14.8	29.4
Threonine[1]	18.6	26.8	12.6	44.2

SB48: soya bean meal 48, SB61: soya bean protein concentrate, SF36: sunflower meal 36, P77: potato protein concentrate.
[1] Data obtained from FEDNA [9].

Table II. Ingredients, chemical composition, pH, acid-buffering capacity and hydration capacity of the experimental diets.

	Diets			
	SB48	SB61	SF36	SB48-P77
Ingredient (g·kg^{-1})				
Wheat	290	286	276	286
Lard	10	14	12	11
Sunflower meal 36	0	0	172	0
Soya bean meal 48	129	0	0	75
Soya bean protein concentrate	0	88	0	0
Potato protein concentrate	0	0	0	30
Wheat bran	172	204	197	182
Sunflower hulls	70	50	23	60
Soya bean hulls	31	32	0	40
Alfalfa hay	270	295	291	290
Alfalfa hay-Yb	6.5	6.5	6.5	6.5
Dicalcium phosphate	2.5	1.9	2.1	2.5
Calcium carbonate	0	3.3	0	0
Sodium chloride	4.9	6.0	4.9	4.9
L-Lysine HCl 78	2.3	2.4	4.7	1.9
DL-Methionine 99	0.7	0.6	0	0.4
L-Threonine	0.8	0.7	1.1	0.3
Vitamin/mineral premix[1]	5.0	5.0	5.0	5.0
Antibiotics	5.0	5.0	5.0	5.0
Chemical composition (g·kg^{-1} DM)				
Dry matter	933	941	938	943
Ash	68	74	73	69
Crude protein	193	203	197	201
Starch	241	244	240	239
Neutral detergent fibre	332	337	324	329
Acid detergent fibre	181	180	177	184
Acid detergent lignin	49	50	50	50
Lysine[2]	10.7	10.6	10.7	10.6
Methionine[2]	3.38	3.34	3.26	3.32
Methionine + cystine[2]	6.43	6.38	6.42	6.36
Threonine[2]	7.50	7.44	7.46	7.42

Table II. *(continued)*

	Diets			
	SB48	SB61	SF36	SB48-P77
DE ($MJ \cdot kg^{-1}$ DM)[2]	11.2	11.1	11.1	11.0
Digestible CP/DE ($g \cdot MJ^{-1}$)[2]	11.8	11.9	11.7	12.1
Physico-chemical characteristics				
pH[3]	6.03	6.02	6.05	6.06
Acid-buffering capacity[4]	228	231	237	227
Hydration capacity (%)	340	317	317	297

SB48: soya bean meal 48, SB61: soya bean protein concentrate, SF36: sunflower meal 36, P77: potato protein concentrate.
[1] Provided by Trouw Nutrition España, S.A. (Madrid, Spain). Mineral and vitamin composition: vitamin A, 8,375 $IU \cdot kg^{-1}$; vitamin D_3, 750 $IU \cdot kg^{-1}$; vitamin E, 20 $IU \cdot kg^{-1}$; vitamin K_3, 1 $mg \cdot kg^{-1}$; vitamin B_2, 2 $mg \cdot kg^{-1}$; vitamin B_6, 1 $mg \cdot kg^{-1}$; vitamin B_1, 1 $mg \cdot kg^{-1}$; vitamin B_3, 20 $mg \cdot kg^{-1}$; Fe: ($FeSO_4$), 76 $mg \cdot kg^{-1}$; Zn: (ZnO), 59 $mg \cdot kg^{-1}$; Mn: (MnO), 20 $mg \cdot kg^{-1}$; Cu: ($CuSO_4$), 10 $mg \cdot kg^{-1}$; Co: ($CoCO_3$), 0.7 $mg \cdot kg^{-1}$; I: (KI), 1.3 $mg \cdot kg^{-1}$; Choline, 250 $mg \cdot kg^{-1}$; S, 275 $mg \cdot kg^{-1}$; BHA-etoxiquin, 54 $mg \cdot kg^{-1}$; flavofosfolipol, 2.5 $mg \cdot kg^{-1}$; Robenidine, 60 $mg \cdot kg^{-1}$.
[2] Calculated from ingredient composition according to FEDNA [9].
[3] pH of 0.5 g DM suspended in 50 mL distilled water.
[4] Acid-buffering capacity: microequivalents of HCl required to lower pH of 0.5 g DM suspended in 50 mL distilled water to pH 2, divided by total pH change (initial pH minus 2).

individually in flat-deck cages measuring 610 × 250 × 330 mm high, except for digestibility trials where they were kept in wire metabolism cages (405 × 510 × 320 mm) that allowed the separation of faeces and urine. A cycle of 12 h of light and 12 h of dark was used throughout the experiments. Heating and forced ventilation systems allowed the building temperature to be maintained between 15 and 24 ºC. Rabbits were handled according to the principles for the care of the animals in experimentation published by the Spanish Royal Decree 223/88 [23].

2.3. Digestibility trial

Thirty-six rabbits weighing 559 ± 38 (SE) g at 25 d of age, were blocked by litter and assigned at random to the experimental diets (9 per diet) to determine the apparent digestibility of dry matter (DM) and crude protein (CP). Following a one-week adaptation period, the feed intake and total faecal output (caecotrophy was not prevented) were recorded from 32 to 36 d of age for each rabbit.

2.4. Ileal digestibility trial

Fifty-six rabbits weighing 437 ± 30 (SE) g at 25 d of age were blocked by litter and assigned at random to the experimental diets (14 per diet) to determine the ileal apparent digestibility of DM and CP. Daily gain and feed intake were recorded for each rabbit during a 10-d adaptation period. Following the adaptation period, the animals weighing 849 ± 46 g were slaughtered by cervical dislocation between 19:00 and 21:00 h to avoid caecotrophy influence on the chemical composition of the ileal digesta [20]. The last 20 cm of the ileum were taken and the ileal contents were removed, frozen and freeze-dried. The samples were then ground and, because of the small quantity of the sample, pooled in groups of two rabbits of the same treatment to analyse crude protein and ytterbium. Ileal digestibility of CP was determined by the dilution technique of a marker. Ytterbium content of experimental diets and ileal digesta were analysed to calculate CP ileal apparent digestibility (CP_{id}, %) according to the following equation:

CP_{id} = [1 – (dietary ytterbium concentration × ileal crude protein concentration/ileal ytterbium concentration × dietary crude protein concentration)] × 100.

2.5. Digestion traits

Forty-four rabbits weighing 429 ± 28 (SE) g at 25 d of age were blocked by litter and assigned at random to the experimental diets (11 per treatment). At 35 d, the animals were slaughtered between 19:00 and 21:00 h weighing 826 ± 45 g. Weight gain and feed intake were registered throughout the 10-d feeding period. After slaughter, a sample of 5 cm was taken from the middle of the jejunum. The intestinal histology was measured according to Hampson [17]. Jejunal samples were rinsed with a solution of 0.4 M KCl and were placed into a 10% buffered neutral formaldehyde solution (pH 7.2–7.4). All samples were gradually dehydrated through an increasing concentration of ethyl alcohol (50–100%). These specimens were first embedded in paraffin, and the samples were prepared by sectioning at 6 μm and stained with hematoxylin and eosin. Both villus height and crypt depth were determined in four jejunal cross-sections per animal by averaging at least 15 measurements. The gastrointestinal tract was removed and the stomach and caecum were weighed with and without their contents. The pH of caecal and stomach contents was measured. In the stomach digesta, three measurements of pH were taken: in the pyloric and fundus areas, and in the mixture of both areas. After that, a sample of caecal contents was centrifuged at 25 000 × *g* at 0 °C for 10 min. The supernatant fluid was acidified with a solution of 0.2 M hydrochloric acid (1 mL per mL), and then frozen until ammonia determination.

2.6. Growth trial

Two hundred and four rabbits weighing 500 ± 16 (SE) g at 25 d of age were blocked by litter and assigned at random to the different treatments (51 per diet). After weaning, the rabbits were individually caged and were fed the experimental diets through a two-week period. After that, all the animals were fed a commercial feed (CUNIUNIC®, NANTA, S.A.: 170 g CP, 144 g starch, 373 g neutral detergent fibre and 49 g acid detergent lignin per kg, 100 ppm of Zn-bacitracin) until they reached the slaughter age (60 days). Feed intake, weight of the rabbits and mortality rate at days 7 and 14 after weaning and at 60 days of age were recorded per cage. Another group of two hundred and forty-eight rabbits weighing 498 ± 17 (SE) g at 25 d of age were blocked by litter and assigned at random to the different treatments (62 per diet). After weaning, the rabbits were caged in pairs of the same litter and only mortality was controlled.

2.7. Analytical methods

Procedures of the AOAC [1] were used for DM (930.15), CP (954.01), and starch (amyloglucosidase-α-amylase method, 996.11). Neutral detergent fibre, acid detergent fibre, and acid detergent lignin were determined according to the sequential procedure of Van Soest et al. [24]. The acid-buffering capacity and pH of the diets were determined according to Jasaitis et al. [18]. The procedure of Das and Arora [5] was used to determine the hydration capacity of the diets. The ytterbium contents of the marked diets and faeces were analysed by atomic absorption (Yb) spectrometry (Smith-Hieftje 22, Thermo Jarrell Ash, MA, USA) using predosed samples of faeces to prepare common-matrix standards. Previously, samples were ashed (550 °C) and then digested by boiling with a solution of 1.5 M HNO_3 and KCl (3.81 $g \cdot L^{-1}$). Caecal ammonia was analysed using an autoevaluation distillation unit. The samples were distilled with a solution of sodium tetraborate (2.5%), collected on boric acid solution (1%), and titrated with hydrochloric acid (0.01 N) and a colour indicator.

2.8. Statistical analysis

The data were analysed as a completely randomised block design with the litter as a block effect. The main factor studied was the source of protein. Weaning weight was used as a linear covariate in all the growth traits studied. The data are presented in tables as least-square means. The protected LSD test was used to make mean comparisons among treatments. The General Linear Model (GLM) procedure of SAS (Statistical Analysis Systems Institute Inc., Cary, NC) was used for all the statistical analyses.

3. RESULTS

3.1. Digestibility

The effect of the treatments on apparent faecal and ileal digestibility is shown in Table III. Food intake from 32 to 35 days of age was not affected by the treatments and averaged 82 g $DM \cdot d^{-1}$. The treatments did not affect faecal DM and CP digestibility (P = 0.81 and 0.95, respectively), which were on average 65.4 and 77.4%, respectively. The type of the diet affected ileal digestibilities of DM and CP (P = 0.03 and P = 0.04, respectively), which were around 14 and 7% higher for SB61 and SF36 diets, respectively, than for the SB48 diet, whereas the values obtained for the SB48-P77 diet were intermediate and did not differ (P > 0.05) with respect to the other three diets. The ileal flux of CP tended (P = 0.08) to be affected by the source of the protein, increasing by around 25% in animals fed the SB48-P77 diet compared to the other three diets.

Table III. The effect of the source of protein on ileal and faecal apparent digestibility of dry matter and crude protein and ileal flux of protein.

	SB48	SB61	SF36	SB48-P77	SEM[1]	*P*
Dry matter intake ($g \cdot d^{-1}$)	80.2	80.0	75.2	91.7	4.91	0.21
Crude protein intake ($g \cdot d^{-1}$)	14.7	15.4	14.1	17.5	0.92	0.13
Ileal flux of crude protein ($g \cdot d^{-1}$)	4.97	4.64	4.29	5.83	0.37	0.08
Ileal apparent digestibility						
Dry matter (%)	46.4^{a}	54.0^{b}	52.2^{b}	48.5^{ab}	1.90	0.040
Crude protein (%)	66.1^{a}	70.6^{b}	70.8^{b}	67.7^{ab}	1.32	0.030
Faecal apparent digestibility						
Dry matter (%)	66.3	65.4	65.3	64.7	1.21	0.81
Crude protein (%)	78.1	77.5	76.9	77.1	1.82	0.95

SB48: soya bean meal 48, SB61: soya bean protein concentrate, SF36: sunflower meal 36, SB48-P77: mix of soya bean meal 48 and potato protein concentrate.
[1] n = 7 for ileal digestibility and n = 9 for faecal digestibility.
[a, b] Diets with different superscripts differ significantly (P < 0.05).

3.2. Digestion traits

The effect of the treatments on several digestion traits and jejunal morphology is shown in Table IV. The caecal concentration of $N\text{-}NH_3$ was 47% higher ($P = 0.0087$) in animals fed the SB48-P77 diet with respect to the animals fed the SB61 diet, whereas the animals fed the SB48 and SF36 diets showed intermediate values. The treatments had no effect on stomach pH (on average 1.59, 2.71 and 2.25 for the pylorus, fundus and the mixed digesta, respectively), caecal pH (5.51, on average), weight of the stomach and stomach content, and caecum and caecum content (1.49, 3.74, 2.11 and 7.87% BW, on average, respectively).

The treatments did not affect the villus height, crypt depth and the ratio villus height/crypt depth, which were on average 494 µm, 73.1 µm and 7.21, respectively.

3.3. Growth performance

The effect of the treatments on growth performance and mortality is shown in Table V. Food efficiency the first week after weaning was affected by the treatments ($P = 0.008$) and was 9 and 11% higher in animals fed the SB61 diet than that observed for animals fed the SB48 and SB48-P77 diets, respectively, whereas the value obtained for the SF36 diet did not differ from those obtained with the SB48 and SB61 diets and was 7% higher than that observed for the SB48-P77 diet. In this period, the type of diet tended ($P = 0.08$) to affect daily gain and food intake, with the lowest values obtained for the SB48 diet. Differences

Table IV. The effect of protein source on digestion traits and jejunal morphology.

	SB48	SB61	SF36	SB48-P77	SEM[1]	*P*
Digestion traits						
Pylorus pH	1.59	1.58	1.49	1.68	0.137	0.24
Fundus pH	3.27	2.71	2.44	2.42	0.426	0.66
Pylorus + Fundus pH	2.55	2.32	2.08	2.05	0.196	0.29
Caecal pH	5.47	5.56	5.54	5.50	0.057	0.30
Empty stomach wt (%) BW	1.45	1.49	1.56	1.45	0.051	0.42
Stomach content wt (%) BW	4.25	4.27	3.33	3.13	0.357	0.06
Empty caecum wt (%) BW	2.26	2.02	2.09	2.09	0.097	0.31
Caecal content wt (%) BW	7.97	7.50	7.58	8.42	0.395	0.37
Caecal $N\text{-}NH_3$ ($mmol \cdot L^{-1}$)	5.36^{ab}	4.70^{a}	5.29^{ab}	6.91^{b}	0.576	0.05
Jejunal morphology						
Villus height (µm)	497	485	497	494	26.3	0.99
Crypt depth (µm)	68.7	79.8	75.3	68.6	6.52	0.59
Villus height/crypt depth	7.68	6.40	6.88	7.89	0.652	0.38

SB48: soya bean meal 48, SB61: soya bean protein concentrate, SF36: sunflower meal 36, SB48-P77: mix of soya bean meal 48 and potato protein concentrate.
[1] n = 11.
[a, b] Diets with different superscripts differ significantly ($P < 0.05$).

Table V. The effect of protein source on growth performance at different periods of age.

	SB48	SB61	SF36	SB48-P77	SEM[1]	*P*
Period 25-32 d of age						
Daily gain (g)	36.6	40.6	40.5	39.0	1.24	0.08
Daily food intake (g)	61.0	63.6	64.4	66.1	1.34	0.08
Food efficiency (g gain/g intake)	0.600[bc]	0.656[a]	0.632[ab]	0.589[c]	0.013	0.008
Mortality (%)	6.74	5.07	6.73	6.80	3.19	0.98
Period 25-39 d of age						
Daily gain (g)	40.1	41.2	42.2	40.0	1.16	0.49
Daily food intake (g)	72.3	72.9	75.2	73.6	1.70	0.62
Food efficiency (g gain/g intake)	0.555	0.577	0.563	0.540	0.009	0.06
Mortality (%)	14.9	14.9	11.9	24.2	4.83	0.31
Whole period, 25-60 d of age						
Daily gain (g)	41.5	42.3	42.1	40.1	0.73	0.18
Daily food intake (g)	115	116	116	114	1.83	0.91
Food efficiency (g gain/g intake)	0.365	0.366	0.362	0.352	0.004	0.06
Mortality (%)	19.9[a]	16.6[a]	13.6[a]	34.6[b]	5.25	0.03

SB48: soya bean meal 48, SB61: soya bean protein concentrate, SF36: sunflower meal 36, SB48-P77: mix of soya bean meal 48 and potato protein concentrate.
[1] Initial number of animals for fattening performance = 51; Initial number of animals for mortality = 113.
[a, b, c] Diets with different superscripts differ significantly ($P < 0.05$).

among treatments for all these traits decreased when it was considered the whole post-weaning period (up to 39 d of age) or the whole fattening period (up to 60 d of age), but food efficiency still remained lower for the animals fed SB48 and SB48-P77 than for the animals fed the other treatments.

The treatments had no effect on mortality in the first two weeks after weaning ($P = 0.31$). However, mortality in the whole fattening period was affected by the source of protein ($P = 0.03$), since it was higher in the animals fed the SB48-P77 diet after weaning than the animals fed the other three diets (34.6 vs. 16.7%, respectively).

4. DISCUSSION

The treatments had no effect on stomach pH that showed low values, which were similar to those previously determined by García et al. [11] and Gutiérrez et al. [15]. These acid values of pH suggest an adequate pepsinogen activation in the stomach content in early weaned 35-d old rabbits.

The treatments had no effect on jejunal morphology although SB48 was substituted with low antigenic sources of protein. However, the sources of protein used in this work influenced ileal apparent digestibility of crude protein. This effect might reflect differences in the small intestinal digestion efficiency, but might also be related to differences in the ileal flux of endogenous nitrogen. According to García et al. [12] endogenous nitrogen flow at the ileum is high in rabbits and accounts for 60–80% of the total ileal flow of nitrogen, and could be affected by differences in the presence of antinutritive factors or type of fibre among protein sources as occurs in pigs [2]. The differences in ileal digestibility of protein and protein intake among treatments led to wide differences in the ileal flow of crude protein (from 4.29 to 5.83 $g \cdot d^{-1}$), which tended to be positively related to mortality from 25 to 39 d of age (r = 0.94; $P = 0.057$; n = 4) and in the whole fattening period (25–60 d of age) (r = 0.92; $P = 0.081$; n = 4). In this way, animals fed the SB48-P77 diet showed the highest ileal flow of protein, concentration of caecal $N\text{-}NH_3$ and mortality. On the contrary, animals fed the SB61 and SF36 diets showed the lowest values for these traits, whereas the animals fed the SB48 diet had an intermediate behaviour. This is in agreement with previous works in which mortality increased when the diets contained an excess of dietary protein [7] and high amounts of protein could reach the caecum promoting the proliferation of Clostridia in the caecum [16]. Scheele and Bolder [21] also reported an increase of mortality in diets containing soya bean meal compared to those based on animal sources of protein.

In this context, the lack of an effect of sources of protein on apparent faecal digestibility of crude protein emphasises the interest of determining ileal digestibility. Caecal digestion can be estimated by the difference of these two values obtaining the following: 19.9, 11.4, 13.1 and 16.2% for DM and 12.0, 6.9, 6.1 and 9.4 for CP, for SB48, SB61, SF36 and SB48-P77 diets, respectively. These results show a higher caecal digestion of DM and CP for animals fed SB48 and SB48-P77 diets compared to those fed SB61 and SF36 diets. In the case of caecal DM digestibility, this effect might be explained by the significant presence of oligosaccharides and resistant starch in SB48 and P77, respectively. In the case of caecal CP digestibility, differences could be related to a better caecal digestion of proteins that reach the caecum undigested due to the action of ANF or to a higher availability of energy for microorganisms.

Feed efficiency during the fattening period was impaired in animals fed the SB48-P77 diet with respect to those fed the SB61 and SF36 diets, whereas the animals fed the SB48 diet showed an intermediate value. These results might reflect differences in energy fermentation losses among diets, because of the differences in the daily amount of substrate able to be fermented by caecal microflora.

In conclusion, the protein source in isonitrogenous diets of young rabbits affects ileal apparent digestibility of protein. Subsequent variations in ileal protein flow were related to variations in feed efficiency and mortality rate among the treatments. Soya bean protein concentrate 61 and sunflower meal 36 showed the best results for feed efficiency. The mix of soya bean meal (48) and potato protein concentrate showed the worse results for feed efficiency and mortality. The results emphasize the importance of the protein source in the diets of early-weaned rabbits.

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