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WHITE LUPIN BRAN AND ITS EFFECTS ON THE GROWTH PERFORMANCE, CARCASS CHARACTERISTICS AND DIGESTIBILITY OF NUTRIENTS IN FATTENING RABBITS

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Abstract: The purpose of the present study was to evaluate the effects of including white lupin bran (WLB) in a fattening rabbit diet on growth, carcass traits and nutrient digestibility. The C diet (control) based on alfalfa meal, whereas the WLB 5 and WLB 15 diets were based on white lupin bran (crude protein 152 g/kg, neutral detergent fibre 524 g/kg as-fed basis). The WLB 5 diet contained 50 g of white lupin bran/kg instead of 50 g of alfalfa meal/kg, whereas the WLB 15 diet contained 150 g of white lupin bran/kg, 5 g of soybean meal/kg and 10 g of sugar beet pulp/kg instead of 165 g of alfalfa meal/kg. The diets had similar digestible protein/digestible energy ratios. A total of 150 Hyplus rabbits between the ages of 30 to 73 d were randomly allocated into one of 3 groups and fed one of the 3 experimental diets. Additionally, another 30 Hyplus rabbits (10 per dietary treatment) at the age of 30 d were selected to determine coefficients of total tract apparent digestibility (CTTAD) of diets between 63 and 67 d of age. The dietary treatments did not affect the final live weight of rabbits (mean=2969 g). There was a higher feed intake (+30 g/d; $P<0.001$) in both groups of rabbits fed the WLB 5 and WLB 15 diets compared to rabbits fed the C diet, which led to impaired feed conversion ratios ($P<0.001$). Sanitary risk index was not affected by dietary treatment. The rabbits fed the WLB 15 diet exhibited a higher drip loss percentage (+0.65%; $P<0.001$) than the rabbits fed the other diets, as well as a lower dressing-out percentage (by 1.6%; $P=0.024$). The CTTAD of the lignocellulose fraction (acid detergent fibre) was significantly higher in rabbits fed the WLB 5 and WLB 15 diets than in those fed the C diet. White lupin bran may be used as a dietary fibrous by-product without significant impairment of the nutritive value of the diet. This lupin by-product can be included in diets for fattening rabbits up to 15% as a partial replacement of alfalfa meal.

Key Words: rabbit, white lupin by-product, growth performance, carcass traits, digestibility.

INTRODUCTION

The use of agro-industrial by-products in animal feed is important in terms of nutrient recycling, and should be prioritised as a means for by-product elimination (Schader *et al.,* 2015; Van Zanten *et al.,* 2016). Furthermore, the use of these by-products might reduce the costs of feed production and reduce the environmental impact (Bonaudo *et al.,* 2014; Makkar, 2016).

Several kinds of by-products have been investigated in rabbits. In this respect, Nicodemus *et al.* (2002) examined a 15.2% inclusion of sunflower hulls in the diets of growing rabbits, which resulted in lower weight gain and worse feeding efficiency. Klinger *et al.* (2015) and De Toledo *et al.* (2012) found that soybean hulls could replace alfalfa hay up to 100% in terms of growth performance and carcass quality of growing rabbits. Nicodemus *et al.* (2015) observed that soybean hull and grapeseed meal mixture can be included up to 26.7% in diets for fattening rabbits and lactating does without adverse effects on their performance and health status. Motta Ferreira *et al.* (1996) studied the effects of substituting grape pomace for alfalfa hay, which led to decreased apparent digestibility of crude protein, and therefore to impaired feed conversion. Other studies were conducted to describe and evaluate the inclusion of olive oil manufacturing by-products (De Blas *et al.,* 2015; Dal Bosco *et al.,* 2012). Additional research focused on the effect of

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including bilberry (Dabbou *et al.,* 2017) and tomato (Peiretti *et al.,* 2013) pomace in rabbit diets on meat quality, and both studies showed that meat quality was improved, particularly in terms of lipid composition.

Lupin by-products are generated during feed production for pigs and poultry, as de-hulling lupin seeds is important for these species in terms of increasing their nutritive value (Mieczkowska *et al.,* 2005; Písaříková and Zralý, 2009; Nalle *et al.,* 2010). Volek *et al.* (2013) showed that white lupin hulls seem to be suitable for use in rabbit diets. In addition to lupin hulls, white lupin bran (WLB) may be another useful lupin by-product, but studies including WLB in animal nutrition are lacking.

Therefore, the aim of the present study was to assess the effect of white lupin bran in a fattening rabbit diet on growth performance, carcass characteristics and digestibility of nutrients.

MATERIALS AND METHODS

Experimental diets

Three experimental diets were formulated according to the recommendations of De Blas and Mateos (2010). The C diet (control) consisted of common feed components, whereas the WLB 5 and WLB 15 diets were based on white lupin bran (cultivar Zulika). The WLB 5 diet contained 50 g of white lupin bran/kg instead of 50 g alfalfa meal/kg, whereas the WLB 15 diet contained 150 g of white lupin bran/kg, 5 g of soybean meal/kg and 10 g of sugar beet pulp/kg instead of 165 g of alfalfa meal/kg (Table 1). The experimental diets had similar contents of crude protein (CP), ether extract (EE), starch and digestible energy (DE), and the proportions of neutral detergent fibre (NDF) were similar between diets. The control diet was slightly lower in acid detergent fibre (ADF) and higher in acid detergent lignin (ADL) than the other 2 diets. The diets were designed to have similar digestible protein (DP)/DE ratio (Table 1).

The white lupin bran was obtained by scraping lupin seeds, during which a certain part of the kernel was scraped together with the hull. The diets were offered to rabbits in the form of pellets that were 3 mm in diameter and 5-10 mm in length. All the diets contained a coccidiostat (66 mg of robenidine hydrochloride/kg of feed; Alpharma, Belgium).

Rabbit husbandry and experimental design

This research was approved by the Ethics Committee of the Institute of Animal Science and was conducted in accordance with recommendations and guidelines for applied nutrition experiments in rabbits (Fernández-Carmona *et al.,* 2005).

A total of 150 Hyplus rabbits (789±10 g live weight) that were 30 d old were randomly allocated to one of 3 groups and fed one of the experimental diets for 43 d. Rabbits were housed in wire net cages (80×60×45 cm; 5 rabbits per cage). Diets were offered to rabbits *ad libitum*. Rabbit live weight and feed intake were recorded per cage; live weight was measured at weekly intervals, whereas feed intake was measured daily. Health status of the digestive tract was assessed every day through individual observation of clinical signs of digestive disorders such as diarrhoea, mucus in faeces and abnormal caecotrophy according to the methodology described by Fernández-Carmona *et al.* (2005). At the end of the experiment 20 rabbits from each group were randomly selected, weighed, slaughtered without previous fasting and used for the evaluation of carcass characteristics, following the methodology recommended by Blasco and Ouhayoun (1996).

An additional 30 Hyplus rabbits (829±204 g live weight), aged 30 d, were used in a digestibility experiment to determine the coefficients of total tract apparent digestibility (CTTAD) for organic matter, CP, gross energy (GE), EE, starch, NDF and ADF of the experimental diets according to the methodology described by Pérez *et al.* (1995). The rabbits were housed in individual digestibility cages (50×40×42.5 cm) and assigned at random to one of the 3 experimental diets (10 rabbits per diet). Rabbits were fed *ad libitum*. Following an adaptation period of 33 d, daily feed intake and total faeces collections were recorded when rabbits were between the ages of 63 to 67 d.

Chemical analyses

AOAC International (2005) procedures were used to determine the dry matter (934.01), CP (954.01), EE (920.39), ADF (973.18) and starch (920.40) in diets, white lupin bran and faeces. Neutral detergent fibre, exclusive of residual

Table 1: Ingredient and chemical composition (g/kg as-fed basis unless otherwise stated) of white lupin bran (WLB), control diet and experimental diets with inclusion of WLB at 5 (WLB 5) and 15% (WLB 15).

		Diets		
	White lupin bran	Control	WLB 5	WLB 15
Ingredients				
Lupin bran	-	0	50	150
Alfalfa meal	-	300	250	135
Soybean meal	-	45	45	50
Wheat bran	-	330	330	330
Sugar beet pulp	-	90	90	100
Oat	-	130	130	130
Barley	-	75	75	75
Vitamin and mineral premix[1]	-	10	10	10
Limestone	-	10	10	10
Sodium chloride	-	5	5	5
Dicalcium phosphate	-	5	5	5
Determined values				
Dry matter	889	878	879	881
Crude protein	152	153	153	152
Ether extract	34	25	24	24
Neutral detergent fibre	524	370	369	375
Acid detergent fibre	431	176	196	197
Acid detergent lignin (ADL)	46	58	47	51
ADL/cellulose ratio	-	0.49	0.32	0.35
Starch	-	151	151	151
Lysine	8.2	7.5	7.4	7.5
Threonine	5.2	6.2	6.1	5.9
Methionine + Cysteine	2.9	5.1	4.9	5.0
Calculated values[2]				
Digestible protein (DP)	-	101	105	104
Digestible energy (DE, MJ/kg)	-	9.2	9.3	9.4
DP/DE ratio (g/MJ)	-	11.0	11.3	11.1

[1]Included per kg of feed: vitamin A, 12000 IU; vitamin D_3, 2000 IU; vitamin E, 50 mg; vitamin K_3, 2 mg; vitamin B_1, 3 mg; vitamin B_2, 7 mg; vitamin B_6, 4 mg; niacinamide, 50 mg; Ca-pantothenate, 20 mg; folic acid, 1.7 mg; biotin, 0.2 mg; vitamin B_{12}, 0.02 mg; choline chloride, 600 mg; Co, 1 mg; Cu, 20 mg; Fe, 50 mg; I, 1.2 mg; Mn, 47 mg; Zn, 50 mg; Se, 0.15 mg; L-lysine, 500 mg; L-threonine, 1000 mg; DL-methionine, 500 mg; Robenidine, 66 mg;
[2]Calculated from digestibility coefficients obtained in the digestibility trial (between d 63 and 67 of age; Table 2).

ash, was assayed with heat-stable amylase (Mertens, 2002). Acid detergent lignin levels were determined by solubilisation of cellulose with sulphuric acid (Robertson and Van Soest, 1981). Gross energy was determined in an adiabatic calorimeter (C5000 control, IKA-Werke, Staufen, Germany). To determine the amino acid content samples of diets and white lupin bran were hydrolysed in 6 M hydrochloric acid at 110°C for 23 h and analysed using an Amino Acid Analyser AAA-400 (INGOS Ltd., Prague, Czech Republic) equipped with an ion-exchange column. Cysteine and methionine were ascertained as cysteic acid and methionine sulphone, respectively, after oxidation with performic acid at 5°C for 16 h. A post-column derivatisation using ninhydrin was used.

Statistical analysis

The data on growth performance, carcass characteristics and CTTAD of the diets were analysed by one-way analysis of variance using the GLM procedure of SAS (2003). For growth performance, cage was the experimental unit. Cages with greater than 50% rabbit mortality (i.e., 3 or more) were excluded from statistical analyses. For the carcass characteristics and CTTAD, the individual rabbit represented the experimental unit. The results are presented as the

Table 2: Coefficients of totat tract apparent digestibility (CTTAD) of the control diet and experimental diets with inclusion of WLB at 5 (WLB 5) and 15% (WLB 15) for rabbits between ages 63 and 67 d.

	Diets				
	Control	WLB 5	WLB 15	RMSE[1]	*P*-value
Rabbits (n)	10	10	10		
Live weight at 63 d (g)	2367	2385	2332	215	0.875
Average daily feed intake[2] (g)	210.8	201.4	201.8	26.4	0.705
CTTAD					
Organic matter	0.583	0.578	0.607	0.035	0.209
Crude protein	0.663	0.686	0.681	0.026	0.194
Gross energy	0.570	0.575	0.585	0.017	0.149
Ether extract	0.848	0.861	0.872	0.023	0.108
Starch	0.940	0.943	0.947	0.008	0.211
Neutral detergent fibre	0.281	0.277	0.299	0.036	0.394
Acid detergent fibre	0.147[a]	0.200[b]	0.210[b]	0.031	<0.001

[1]Root mean square error (n=10 rabbits per diet).

[2]Average daily feed intake during the digestibility trial (between ages 63 and 67 d).

[a, b]Means with different superscripts differ significantly at $P<0.05$.

means followed by the root mean square error. Means were compared using the Scheffe test. Health status was assessed using Fisher's exact test. The individual rabbit was used as the experimental unit. All differences were considered to be significant at $P<0.05$

RESULTS AND DISCUSSION

When comparing the chemical composition of white lupin bran (Table 1) and white lupin hulls (Volek *et al.,* 2013), white lupin bran contained more CP and EE, and less NDF, ADF and ADL. This finding was caused by different methods of obtaining these by-products, which altered their different characteristics. In fact, Volek *et al.* (2013) manually removed just the hulls from the white lupin seed, whereas in the present study white lupin bran was obtained using a machine to scrape the seeds, so that a small portion of the kernel was scraped together with the hull.

Table 3: Growth performance and health status of rabbits fed the control diet and experimental diets with inclusion of WLB at 5 (WLB 5) and 15% (WLB 15) between 30 and 73 d of age.

	Diets				
	Control	WLB 5	WLB 15	RMSE[1]	*P*-value
Growth performance					
Rabbits (n)	45	41	43		
Live weight at weaning (30 d; g)	793	796	777	58	0.752
Live weight at 73 d (g)	2883	3030	2994	223	0.340
Average daily weight gain (g)	48.6	51.9	51.6	4.3	0.203
Average daily feed intake (g)	127.4[a]	157.6[b]	157.1[b]	15.6	<0.001
Feed conversion ratio	2.62[a]	3.03[b]	3.05[b]	0.20	<0.001
Health status					
Rabbits (n)	50	50	50		
Number of dead rabbits	5	9	7	-	0.388
Number of morbid rabbits	6	5	4	-	1.000
Sanitary risk index[2] (n)	11	14	11	-	0.645

[1]Root mean square error (n=10, 9 and 9 cages for the Control, WLB 5 and WLB 15 diets, respectively; 5 rabbits per cage).

[2]Sum of dead and morbid rabbits (a morbid animal that later died was count as dead).

[a, b]Means with different superscripts differ significantly at $P<0.001$.

Table 4: Carcass traits of rabbits fed the control diet and experimental diets with inclusion of WLB at 5 (WLB 5) and 15% (WLB 15) at age 73 d.

	Diets				
	Control	WLB 5	WLB 15	RMSE[1]	*P*-value
Rabbits (n)	20	20	20		
Slaughter weight (g)	3001	3048	2903	343	0.405
Full digestive tract (g/kg SW[2])	460	459	423	64	0.125
Skin (g/kg SW)	519	500	504	76	0.715
Hot carcass weight (g)	1837	1834	1726	237	0.249
Chilled carcass weight (g)	1793	1787	1671	233	0.191
Dressing-out percentage[3] (%)	61.1	60.2	59.3	2.5	0.089
Dressing-out percentage[4] (%)	59.6[b]	58.6[b]	57.5[a]	2.4	0.024
Drip loss percentage[5] (%)	2.46[a]	2.61[a]	3.18[b]	0.32	< 0.001

[1]Root mean square error (n=20 rabbits per diet).
[2]SW=slaughter weight.
[3]Dressing-out percentage=(hot carcass weight/slaughter weight)×100.
[4]Dressing-out percentage=(chilled carcass weight/slaughter weight)×100.
[5]Drip loss percentage=[(hot carcass weight–chilled carcass weight)/hot carcass weight]×100.
[a, b]Means with different superscripts differ significantly at $P<0.05$.

The data on the CTTAD of the experimental diets are presented in Table 2. The CTTADs of organic matter, CP, GE, EE, starch and NDF were not affected by dietary treatment. The CTTAD of the lignocellulose fraction (ADF) was significantly higher in rabbits fed diets based on white lupin bran than in those fed the control diet, probably due to the lower ratio of lignin to cellulose in these diets (Gidenne *et al.,* 2001). In line with the aim of the dietary formulation, the DP/DE ratio was similar among the diets.

Growth performance of rabbits is presented in Table 3. There were no significant differences in the live weight of rabbits between treatments at age 73 d (on av. 2969 g) or in the average daily weight gain between 30-d-old and 73-d-old rabbits (on av. 50.7 g). Conversely, there was a higher average daily feed intake (+30 g; $P<0.001$) in both groups of rabbits fed diets based on white lupin bran compared to rabbits fed the control diet, which led to an impaired feed conversion ratio (2.62, 3.03 and 3.05 for the control, WLB 5 and WLB 15 diets, respectively; $P<0.001$). These findings are likely associated with the higher ADF levels in the diets based on white lupin bran. Indeed, Gidenne (2015) reported that the voluntary feed intake is more related to the dietary ADF level than to the dietary digestible energy concentration. No significant effect on the health status of rabbits was observed with regard to dietary treatment. Morbidity and mortality was associated with the presence of diarrhoea and mucus in faeces.

Carcass characteristics data are presented in Table 4. There were no significant differences between dietary treatments with regard to the hot carcass weight or chilled carcass weight. In line with the study by Laudadio *et al.* (2009), we observed an effect of the dietary treatments on a drip loss percentage. In fact, rabbits fed the WLB 15 diet exhibited a higher drip loss percentage (+0.65%) compared to rabbits fed the other diets ($P<0.001$); this finding is likely associated with a reduction in dressing-out percentage by 1.6% ($P=0.024$).

CONCLUSION

White lupin bran may be used as a dietary fibrous by-product without reducing the nutritive value of the diet, and can be included in diets given to fattening rabbits up to 15% as a partial replacement of alfalfa meal. However, future research should focus on finding of the maximal suitable dietary level for lupin bran with regard to the dressing out percentage and drip loss.

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