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DRIED CHICORY ROOT (*CICHORIUM INTYBUS L.*) AS A NATURAL FRUCTAN SOURCE IN RABBIT DIET: EFFECTS ON GROWTH PERFORMANCE, DIGESTION AND CAECAL AND CARCASS TRAITS

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Abstract: Three experimental diets were formulated including (per kg) 0, 50 or 100 g chicory root (Control, Chicory 5, Chicory 10 diets, respectively) at the expense of oats. The diets differed with respect to starch and fructan contents. In the performance trial, 120 Hyplus rabbits were randomly allocated to 3 groups (2 rabbits per cage) and fed one of the 3 experimental diets between 31 and 73 d of age. At the end of the trial period, 20 rabbits per treatment were slaughtered and used for evaluation of carcass traits. In addition, the coefficients of total tract apparent digestibility (CTTAD) of the diets and caecal traits were determined from 45 to 49 d of age in 10 rabbits per treatment. The diets did not differ significantly in terms of weight gain, feed intake, feed conversion ratio, health status or carcass traits of rabbits. The CTTADs of crude protein (P=0.041) and ether extract (P=0.006) were lower in rabbits fed the Chicory 10 diet than in rabbits fed the control diet. The CTTAD of starch (P<0.001) was lower, whereas that of fructans (P<0.001) higher, in rabbits fed the diets based on chicory root. The caecum weight (P=0.037), the weight of its contents (P=0.025) and the lactic acid (P=0.028) concentration were higher in rabbits fed the Chicory 10 diet than in control rabbits. On the contrary, rabbits fed with the chicory diets showed lower caecal pH (P=0.048) than rabbits fed the control diet. There was a non-significantly lower caecal dry matter content (P=0.077) and higher total VFA concentration (P=0.065) with the chicory root inclusion. It may be concluded that chicory root can serve as a natural source of inulin-type fructans in rabbit feed. Diet supplementation with 10% dried chicory root beneficially affected the caecal fermentative activity in the rabbits, without significant reductions in the nutritive value of the diet, growth performance or carcass quality.

Key Words: rabbit, diet, chicory root, digestion, caecum, growth performance.

INTRODUCTION

There is some evidence in the literature suggesting that inulin-type fructans are important components of the diets of companion animals and livestock (review of Flickinger *et al.*, 2003). In rabbits, it has been shown that a diet containing inulin-type fructans affects the caecal microbial activity, morbidity and growth rate in a beneficial way (Morisse *et al.*, 1993; Maertens *et al.*, 2004; Volek *et al.*, 2005, 2007; Eiben *et al.*, 2008) or not (Bónai *et al.*, 2010).

The fructans used in previous experiments were commercially available preparations, which may be too expensive from a practical point of view. For this reason, plant sources rich in fructans are worth investigating, e.g. chicory root. Inulin-type chicory fructans typically contain more than

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70% of inulin, some low-molecular mass sugars, organic acids, protein fragments and minerals (Van Loo, 2007). Castellini *et al.* (2007) reported that fresh chicory leaves and roots, when fed together with a pellet diet, may represent a suitable fructan source for rabbits.

Thus, the objective of this study was to evaluate the use of dried chicory root as a feed ingredient by determining nutrient digestibility, caecal fermentative activity, growth performance and carcass traits of growing rabbits.

MATERIALS AND METHODS

Experimental diets

The ingredients and chemical composition of the diets are shown in Tables 1 and 2, respectively. Three experimental diets were formulated including (per kg) 0 (Control diet), 50 (Chicory 5 diet) or 100 g dried chicory root (Chicory 10 diet) at the expense of oats. The diets were designed to have similar levels of crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), ether extract (EE), and digestible energy (DE). The experimental diets differed mainly in the starch and fructan contents. Diets were pelleted (3 mm × 5-10 mm length) and animals were given *ad libitum* access to feed and water throughout the experiment. Apart from salinomycin, an ionophore used to control coccidiosis, no other medication was included in the feed or drinking water.

Rabbit husbandry and experimental design

The study was approved by the Ethics Committee of the Institute of Animal Science and the Central Commission for Animal Welfare at the Ministry of Agriculture of the Czech Republic and was carried out according to the guidelines for applied nutrition experiments in rabbits (Fernández-Carmona *et al.*, 2005). The experiment was conducted in a rabbit facility of the Institute of Animal Science. Animals were kept under controlled environmental conditions: room temperature between 16 and 20°C, relative humidity of approximately 65% and 12 h of light per day.

Table 1: Ingredient composition (g/kg as fed basis) of the experimental diets.

	Control	Chicory 5	Chicory 10
Alfalfa meal	280	280	280
Soybean meal, CP (440 g/kg)	90	90	90
Wheat bran	320	320	320
Sugar beet pulp	70	50	45
Dried chicory root	0	50	100
Oats grain	100	50	0
Barley grain	90	110	110
Rapeseed oil	20	20	25
Vitamin supplement[1]	10	10	10
Dicalcium phosphate	5	5	5
Limestone	10	10	10
Salt	5	5	5

[1]Included per kg of feed: vitamin A, 12000 IU; vitamin D3, 2000 IU; vitamin E, 50 mg; vitamin K3, 2 mg; vitamin B1, 3 mg; vitamin B2, 7 mg; vitamin B6, 4 mg; niacinamide, 50 mg; Ca-pantothenate, 20 mg; folic acid, 1.7 mg; biotin, 0.2 mg; vitamin B12, 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; salinomycin, 22.5 mg.

Table 2: Chemical composition (g/kg as-fed basis unless otherwise stated) of the experimental diets and dried chicory root.

	Chicory root	Control	Chicory 5	Chicory 10
Determined values				
Dry matter	898	910	907	897
Crude protein	60	161	157	155
Neutral detergent fibre	84	369	357	341
Acid detergent fibre	78	176	166	167
Lignin	30	48	41	33
Ether extract	3	43	46	42
Starch	0	153	133	108
Fructans	542	17	42	66
ADF/starch ratio	-	1.15	1.25	1.55
Calculated values				
Digestible crude protein[1]	-	124.1	117.3	113.4
Digestible energy[1] (MJ/kg)	-	11.8	11.8	11.7

[1] Calculated from digestibility coefficients obtained in the digestibility trial.

For the performance trial, 120 Hyplus rabbits (PS 19×PS 39) were randomly assigned to one of the 3 experimental diets from 31 to 73 d of age. Two rabbits were housed in each all-wire cage (80×60×42.5 cm). Feed intake and live weight were recorded per cage, at the beginning (31 d) and end of the trial (73 d) and the daily weight gain, daily feed intake and feed conversion ratio were calculated afterwards. Health status was controlled through individual observation of clinical signs of digestive trouble according to the methodology of the European Group on Rabbit Nutrition (Fernández-Carmona *et al.*, 2005). At the end of the experiment, 20 rabbits per treatment were randomly selected, weighed, slaughtered without previous fasting and used for the evaluation of carcass traits according to the recommendations of Blasco and Ouhayoun (1996). Briefly, the slaughtered rabbits were bled and then the skin, genitals, urinary bladder, gastrointestinal tract and the distal part of legs were removed. Carcasses were weighed (hot carcass weight) and then chilled at +4°C for 24 h in a ventilated room. After chilling, the chilled carcasses were weighed (chilled carcass weight). The head, thoracic cage organs, liver and kidneys were removed from each carcass to obtain the reference carcass, which included the meat, bones and fat depots. The right hind legs were deboned, and the meat:bone ratio was calculated.

In addition, 30 additional Hyplus rabbits (PS 19×PS 39) weaned at 31 d of age were used in a digestibility trial to determine the coefficients of total tract apparent digestibility (CTTADs) of organic matter, CP, gross energy, EE, starch, fructans, NDF, and ADF of the diets, following the European Group of Rabbit Nutrition recommendations (Perez *et al.*, 1995). The rabbits were individually housed in digestibility cages (50×40×42.5 cm) and assigned at random to 1 of the 3 experimental diets (10 per treatment). Following an adaptation period of 14 d, feed intake and total faecal output were individually recorded from 45 to 49 d of age. After the faecal collection period, all rabbits were slaughtered (between 12:00 and 13:00 p.m.) and the caeca were excised, weighed and emptied by gentle squeezing to measure digesta pH. For caecal volatile fatty acids (VFA), lactic acid and ammonia analyses, the caecal content was diluted with distilled water (1:2), and mercury (II) chloride was added to inactivate microbial growth.

Analytical methods

Chemical analysis of diets was performed using the procedure of Van Soest *et al.* (1991) for NDF, ADF and acid detergent lignin (ADL). The AOAC International (2005) procedures were used to determine the CP (954.01) and starch (920.40) contents. EE was determined according to AOAC procedure 920.39 (1995). The dry matter content was determined in duplicate samples by drying the samples at 105°C to a constant weight. Gross energy was measured using an adiabatic calorimeter (C5000 control, IKA-Werke, Staufen, Germany). The fructan contents in the feed and faeces samples were determined using the Fructan Assay Kit (Megazyme, Wicklow, Ireland). The total caecal (VFA) concentration was determined by titration after steam distillation. VFA molar concentration was estimated by gas chromatography at 140°C using a Chromosorb WAW column with 15% SP 1220 and 1% H_3PO_4 (Supelco, Bellefonte, PA, USA). Lactic acid concentration was assayed by the microdiffusion method as describe by Conway (1957). Briefly, lactate was converted into acetaldehyde using cerium (IV) sulphate, and the resulting acetaldehyde (lactate oxidation product) was trapped in 0.01 M semicarbazide HCl in microdiffusion chambers. Ammonia levels were determined colorimetrically with Nessler's reagent after prior separation from interfering compounds by microdiffusion in Conway units.

Statistical analyses

Data on growth performance, caecal and carcass traits, and the CTTAD of the diets were analysed by the General Linear Model using a one-way ANOVA (SAS, 2001) with diet as the main factor. Scheffe's test was used for a comparison of the means when appropriate. Morbidity was analysed using the chi-square test. Differences among treatment means with $P<0.05$ were accepted as representing statistically significant differences.

RESULTS

The diets used were not significantly different with respect to the CTTADs of organic matter, gross energy and fibre fractions (Table 3). The CTTADs of CP ($P=0.041$) and EE ($P=0.006$) were lower in rabbits fed the Chicory 10 diet than in rabbits fed the control diet. The CTTAD of starch

Table 3: Coefficients of total tract apparent digestibility (CTTAD) of the experimental diets for rabbits between 45 and 49 d of age.

	Control	Chicory 5	Chicory 10	RMSE[1]	*P*-
Feed intake[2] (g/d)	158.8	167.3	153.8	20.3	0.340
CTTAD					
Organic matter	0.682	0.689	0.689	0.023	0.752
Crude protein	0.771[b]	0.747[ab]	0.735[a]	0.030	0.041
Gross energy	0.687	0.690	0.690	0.023	0.927
Ether extract	0.908[b]	0.910[b]	0.888[a]	0.015	0.006
Starch	0.953[c]	0.947[b]	0.933[a]	0.005	<0.001
Fructans	0.978[a]	0.996[b]	0.996[b]	0.005	<0.001
NDF[3]	0.435	0.430	0.418	0.049	0.750
ADF[4]	0.345	0.339	0.341	0.052	0.957

Means in the same row with different letters (a, b and c) differ significantly ($P<0.05$). [1]RMSE=root mean square error (n = 10 rabbits per treatment). [2]Feed intake during the digestibility trial (45 to 49 d of age). [3]Neutral detergent fibre. [4]Acid detergent fibre.

Table 4: Caecal parameters and caecal fermentative activity at 49 d of age in rabbits fed the experimental diets.

	Control	Chicory 5	Chicory 10	RMSE[1]	*P*-value
Live weight[2] (g)	1886	1940	1856	202	0.642
Full organ (g/kg LW)	56.6[a]	60.9[ab]	62.4[b]	5.0	0.037
Fresh content (g/kg LW)	39.8[a]	43.7[ab]	48.8[b]	4.9	0.025
Dry matter (%)	24.0	23.3	22.6	1.3	0.077
pH	6.47[b]	6.19[a]	6.21[a]	0.25	0.048
Total VFA[3] (μmol/g)	80.3	101.1	93.3	19.2	0.065
Acetate (mol/100 mol)	75.16	74.56	73.37	4.14	0.624
Propionate (mol/100 mol)	5.13	5.15	4.33	0.90	0.088
Butyrate (mol/100 mol)	18.46	18.96	20.09	3.10	0.492
Other VFA[4] (mol/100 mol)	1.26	1.32	1.26	0.70	0.974
Lactic acid (μmol/g)	0.44[a]	0.47[ab]	0.51[b]	0.06	0.028
Ammonia (μg/g)	188.9	163.6	171.3	39.8	0.359

Means in the same row with different letters (a and b) differ significantly ($P<0.05$). [1]RMSE=root mean square error (n=10 rabbits per treatment). [2]LW=live weight of rabbits at 49 d of age. [3]VFA=volatile fatty acids. [4]Other VFA=isobuty rate+isovalerate+valerate+caproate.

was lower ($P<0.001$), whereas that of fructans higher ($P<0.001$), in rabbits fed the diets based on chicory root when compared with control rabbits.

The caecum weight ($P=0.037$), its content ($P=0.025$) and the lactic acid concentration ($P=0.028$) were higher in rabbits fed the Chicory 10 diet than rabbits fed the control diet (Table 4). On the contrary, rabbits fed with the chicory diets showed lower caecal pH ($P=0.048$) than rabbit fed the control diet. There was a non-significantly lower caecal dry matter content ($P=0.077$) and higher total VFA concentration ($P=0.065$) with the chicory root inclusion.

There were no significant differences among treatments for weight gain (on average 53.4 g/d), feed intake (on average 150.9 g/d) or feed conversion ratio (on average 2.83; Table 5). Although no significant differences were detected, the lowest incidence of diarrhoea was observed in rabbits fed the Chicory 10 diet. No mortality occurred during the experiment. There were no significant differences among treatments on rabbit carcass traits (Table 6).

Table 5: Growth performance (31-73 d of age) of rabbits fed the experimental diets.

	Control	Chicory 5	Chicory 10	RMSE[1]	*P*-value
Live weight (g)					
31 d	799	803	802	102	0.992
73 d	2995	3038	3091	296	0.588
Daily weight gain (g/d)	52.3	53.3	54.5	5.8	0.479
Daily feed intake (g/d)	147.0	150.6	155.0	16.8	0.325
Feed conversion rate	2.81	2.83	2.85	0.12	0.639
Morbidity[2]	5	3	1	-	0.201

[1]RMSE=root mean square error (n=20 cages per treatment). [2]Number of rabbits with diarrhoea.

Table 6. Carcass characteristics of rabbits at 73 d of age fed the experimental diets.

	Control	Chicory 5	Chicory 10	RMSE[1]	*P*-value
Slaughter weight [2] (g)	3000	3013	3092	302	0.579
Full digestive tract (g/kg SW)	146	155	155	18	0.233
Skin (g/kg SW)	166	165	168	15	0.885
Hot carcass weight (g)	1787	1799	1847	216	0.648
Chilled carcass weight (g)	1727	1740	1790	210	0.613
Drip loss percentage (%)	3.3	3.3	3.1	0.5	0.466
Reference carcass weight (RC, g)	1431	1428	1479	181	0.624
Perirenal fat (g/kg RC)	22	22	23	7	0.846
Total dissectible fat[3] (g/kg RC)	36	37	36	8	0.910
Meat:bone ratio	5.55	5.54	5.23	0.90	0.452
Dressing-out percentage[4] (%)	57.5	57.6	57.8	4.9	0.632

[1]RMSE=root mean square error (n=20 rabbits per treatment). [2]SW=slaughter weight. [3]Total dissectible fat includes the scapular, inguinal and perirenal fat.[4] Chilled carcass weight/slaughter weight×100.

DISCUSSION

It follows from this study that chicory root may replace oats (starch source) in rabbit diets because no negative effects on weight gain, feed intake or feed conversion ratio were observed. Additionally, the carcass characteristics were not affected by the dietary treatment and were consistent with the rabbit carcass quality values reported in other studies (review of Dalle Zotte, 2002).

Our results are in agreement with the described importance of inulin-type fructans in rabbit nutrition regarding caecal fermentative activity (Morisse *et al.*, 1993; Maertens *et al.*, 2004; Volek *et al.*, 2005; Castellini *et al.*, 2007; Volek *et al.*, 2007; Juśkiewicz *et al.*, 2008). In the present study, dietary supplementation with dried chicory root affected the total caecal concentrations of VFA and the pH when compared with the control diet; these differences were apparently associated with a non-significant lower incidence of diarrhoea in rabbits fed the Chicory 10 diet (Gidenne and Licois, 2005). Furthermore, there was a significantly higher level of lactic acid in the caecal contents of rabbits fed the Chicory 10 diet than in rabbits fed the other diets, a finding that is consistent with a pig experiment in which a diet containing 8% of inulin was offered (Halas *et al.*, 2009). In our study, the non-significant effect of the chicory diet on the health status of rabbits was due to the high standard of zoohygiene in the rabbit experimental building. As there are contradictory results in the literature, regarding the effect of inulin-type fructans on caecal microbial activity (Bónai *et al.*, 2010), further research should focus on confirming the beneficial effect of dietary fructans on the digestive health of growing-fattening rabbits raised on commercial farms. The mode of fructan action should also be elucidated.

There was a significantly lower CTTAD of CP in rabbits fed the chicory diets, a finding that is consistent with similar findings in rats (Levrat *et al.*, 1993; Vanhoof and De Schrijver, 1996) and pigs (Lynch *et al.*, 2007; Hedemann and Knudsen, 2010) when inulin-rich diets were fed. Additionally, the CTTADs of EE and starch were significantly lower in rabbits fed the chicory diets, probably because of the higher ADF/starch ratio of these diets (Gidenne *et al.*, 2000). The CTTAD of fructans was significantly higher in rabbits fed both diets based on chicory root than in control rabbits, probably due to the higher caecal fermentative activity.

CONCLUSION

It may be concluded that chicory root is a potential natural source of inulin-type fructans for rabbit feed. Diet supplementation with 10% dried chicory root beneficially affected the caecal fermentative activity in the rabbits without significant reductions in the nutritive value of the diet, growth performance or carcass quality.

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