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DEHYDRATED CHICORY PULP AS AN ALTERNATIVE SOLUBLE FIBRE SOURCE IN DIETS FOR GROWING RABBITS

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Abstract: Soluble fibre (SF) is an important nutrient to enhance fermentative activity and gut health in rabbits. The main source of SF in rabbit diets is sugar beet pulp (SBP), whereas, due to its high content of SF (34%), dried chicory pulp (ChP) could be an alternative to SBP. In a fattening trial with 192 hybrid weanlings 32 d old weighing 837±45 g, chicory pulp was used in replacement of SBP to study effects on production performances and slaughter characteristics. Rabbits were fed one of 4 iso-energetic (9.65 MJ digestible energy/kg) and iso-nitrogenous (15.6% crude protein) diets: a negative control (NC) diet with a low dietary SF content (7.3%), a positive control diet with quite a high SBP level (13.5%) and SF content (10.6%) and 2 diets with respectively 10% and 20% of chicory pulp (ChP10: 9.9% SF and ChP20: 13.7% SF). The SF content was measured as the difference between total dietary fibre and neutral detergent fibre, the latter corrected for ash and protein content. Each dietary treatment consisted of 12 replicates of 4 rabbits. Weight gain was high (on av. 54 g/d) and comparable for the NC, SBP and ChP diets. However, feed conversion ratio was improved ($P<0.05$) with the ChP20 diet compared to the NC diet (2.88 *vs*. 2.97). Mortality was low and not influenced by the dietary treatment. Slaughter data were very similar and no effect of the SF level on caecal weight or slaughter yield was observed. It was concluded that chicory pulp is a good alternative soluble fibre source in balanced diets for rabbits and can be used at least up to 20% inclusion rate.

Key Words: rabbit, soluble fibre, chicory pulp, sugar beet pulp.

INTRODUCTION

It has long been known that dietary fibre supply plays a major role in the prevention of digestive troubles in growing rabbits (Lebas, 1980). Moreover, due to improved analytical methods to measure fibre fractions and intensive research, the different fractions (insoluble fibre, soluble fibre) and their roles are now much better defined (Gidenne *et al.* 2003; Trocino *et al.*, 2013).

Recently Trocino *et al.* (2013) defined and discussed total dietary fibre (TDF), insoluble dietary fibre and soluble fibre (SF) and its relevance in terms of rabbit nutrition and digestive health. SF is the part of TDF that comprises the non-starch and non neutral detergent fibre (NDF) polysaccharides, including pectic substances, β-glucans, fructans and gums (Hall, 2003). SF is quantified by different methods or calculations, although the most extensively used in rabbit nutrition research is the difference between TDF and NDF, the latter corrected for ash and protein content (Xiccato *et al.*, 2012).

The insoluble and low-digested fibre fractions (hemicelluloses, cellulose and lignin) affect the digesta retention time (Gidenne and Perez, 1994), whereas the more soluble and highly-digested fibres (hemicelluloses and pectins) promote caecal microbial activity (Peeters *et al.*, 1995; García *et al.*, 2002; Gidenne *et al.,* 2004; Rodríguez-Romero *et al.,*

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2011; Martinez-Vallespin *et al.*, 2013) and a good balance between insoluble fibre and SF may favour intestinal health (Nicodemus *et al.,* 2006; Gómez-Conde *et al.*, 2007; Gómez-Conde *et al.*, 2009; Trocino *et al.,* 2011). In fact, a supply of 12% as-fed SF has been recommended in diets for growing rabbits, containing about 30% NDF and 18% acid detergent fibre (ADF), to maintain mortality due to digestive disorders below 5% (Trocino *et al.*, 2013). However, the effects of high dietary levels of SF (>12%) have not yet been widely investigated; among other results, it may correspond to an increase of caecal content (Peeters *et al.,* 1995; Gómez-Conde *et al.*, 2009; Martinez-Vallespin *et al.*, 2013) which could impair slaughter yield (Falcão-e-Cunha *et al.*, 2004).

On the other hand, the conclusions above on the recommended levels of dietary SF are linked to the use of sugar beet pulp (SBP) in diets as primary source of SF. In fact, in rabbit diets, the main sources of SF are SBP, apple or citrus pulp (Xiccato *et al.*, 2012). An alternative source could be chicory pulp (ChP), known for its high content of inulin and pectin (minimum 7 and 27%, respectively) (Socode, 2013). ChP is the dried and ground product obtained from the chicory root shreds after partial extraction of inulin by diffusion; it contains on average 87% dry matter (DM), 8.8% crude protein (CP), 32.0% NDF, 24.0% ADF and 2.0% lignin (Socode, 2013), and has been shown to have a beneficial effect on caecal fermentative activity in rabbits (Volek and Marounek, 2011).

The aim of our work was to evaluate the effect of the use of ChP at 2 levels of inclusion (10 and 20%), in replacement of SBP and in comparison to a diet with a moderate level of SF, on growth performance and slaughter traits of growing rabbits.

MATERIALS AND METHODS

Animals and housing

Two hundred Hycole crossbred weanling rabbits at 28-29 d of age of both genders were purchased from a commercial French rabbitry and housed at the experimental facilities of ILVO Animal Science Unit. Rabbits were obtained from cross breeding between the female parent line and the XXL male line of Hycole. After an adaptation period of 4 d during which they were fed a standard weaning diet *ad libitum*, 192 rabbits were selected for the trial. A randomised block design was used with four dietary treatments and 12 blocks of 4 cages.

Rabbits at 32 d of age weighing 837±45 g were housed in groups of 4 animals in wire flat-deck cages measuring 45×70 cm and a height of 50 cm. Each cage was equipped with a feeder (2 feeding places) and a nipple drinker. Rabbits were uniquely identified with ear tags and randomised, taking into account their weight in order to have approximately the same average initial weight per cage.

The experimental farm was equipped with dynamic (over-under pressure) ventilation with 2 air inlets at the door side of each compartment and air extraction at the other side of the room. The ventilation rate varied between 1 and 2 m^3/kg live weight/h, depending on the outside temperature. No heating of the incoming air or experimental room was applied during the trial. Temperature varied between 14 and 20°C throughout the experiment. The rabbit house was windowless and a lighting schedule of 10 h light and 14 h dark was used during the whole trial period.

Diets and experimental procedures

Four iso-energetic and iso-nitrogenous diets were formulated using the EGRAN tables (Maertens *et al.,* 2002) (Table 1). A value of 11.3 MJ/kg digestible energy (DE) was assumed for SBP pulp according to Gidenne *et al.* (2007). Lacking any valuable estimation of the DE content, the same energy value was assumed for ChP.

Diets were formulated to have an energy content of 9.65 MJ DE/kg and a CP content of 15.7% (as-fed basis). A diet with low SF content was used without SBP or ChP as negative control diet (NC); the SBP diet contained 13.5% SBP in order to obtain about a 30% higher SF content compared to NC diet; the ChP10 and ChP20 diets contained ChP at 10 and 20%, inclusion rate, respectively, and no SBP. This way, ChP10 diet had quite the same soluble fibre as the SBP diet; ChP20 diet contained a higher level of SF compared to the other diets.

Table 1: Ingredient composition of experimental diets.

	Diet			
	NC	SBP	ChP10	ChP20
Wheat shorts	27.10	25.10	25.10	25.10
Alfalfa meal 17% CP	32.30	29.00	28.00	24.00
Wheat	15.40	6.00	10.00	3.00
Palm cake	4.00	4.00	4.00	3.50
Sunflower meal 27% CP	8.00	10.00	10.00	12.00
Sugar beet pulp	0.00	13.50	0.00	0.00
Chicory pulp	0.00	0.00	10.00	20.00
Flax chaff	7.19	6.44	6.88	6.39
Cane molasses	3.00	3.00	3.00	3.00
$CaCO_3$	0.10	0.10	0.10	0.10
Vitamin-mineral premix[1]	2.50	2.50	2.50	2.50
NaCl	0.10	0.10	0.10	0.10
Methionine	0.10	0.09	0.12	0.12
Lysine	0.19	0.15	0.18	0.17
Clinacox	0.02	0.02	0.02	0.02

[1]The premix contains: 11.9% Ca, 4.4% P and 6.2% Na and vitamin A, 320 IU/g; vitamin D3, 70 IU/g; vitamin E, 0.80 mg/g; vitamin K3, 0.020 mg/g; vitamin B1, 0.020 mg/g; vitamin B2, 0.11 mg/g; Ca-pantothenate, 0.27 mg/g; vitamin B6, 0.020 mg/g; vitamin B12, 0.00060 mg/g; nicotinamide, 0.71 mg/g; choline chloride, 4.46 mg/g; I, 0.0040%; Co, 0.0030%; Se, 0.0012%; Cu, 0.040%; Mn, 0.13%; Zn, 0.24%; Fe, 0.40%; BTH, 0.06%.

All diets were prepared and pelleted (3 mm diameter and 0.8 cm length) at the ILVO Animal Science feed mill. No growth promoter or antibiotics were added to the experimental diets and no treatments were executed during the trial. However, diets were supplemented with 1 mg/kg diclazuril (Clinacox® 0.5%) as anticoccidial.

Diets were always administered *ad libitum* throughout the 5-wk experimental period and rabbit weight gain and feed consumption were controlled per cage on a weekly basis from 32 to 67 d of age. Due to practical reasons, slaughtering were performed 3 d later, at 70 d of age. Ten rabbits per diet were randomly selected and slaughtered, after a feed withdrawal period (starting at 8:00 a.m.) of 5 h, at the Institute's facilities. Carcasses were chilled at 2°C for 20 h and then dissected following standardised procedures (Blasco and Ouhayoun, 1996).

Chemical Analyses

Diets and chicory pulp were analysed for their content in DM (SCD 71/393/EEC), CP (ISO 5983-2), ether extract (ISO 6492), crude fibre (AOCS, 2005). Fibre fractions, that is NDF (without sodium sulphite), ADF, and lignin, were analysed according to Mertens (2002), AOAC (2000, procedure 973.187), and Van Soest *et al.* (1991), respectively, using the sequential procedure and the filter bag system (Ankom Technology, New York) (Uden *et al.*, 2005).

TDF was determined using a gravimetric-enzymatic procedure (AOAC 2000, 991.43) with α-amylase, protease, and amyloglucosidase treatments (Megazyme Int. Ireland Ltd., Wicklow, Ireland). The amount of soluble fibre was calculated by subtracting the NDF from the TDF after correcting for crude protein and ash (Van Soest *et al.*, 1991; Xiccato *et al.*, 2012).

Statistical analyses

Cage data on daily weight gain, feed intake and feed conversion ratio were analysed as a completely randomised block design using a mixed model (StatSoft, 2012) with diet as main factor and block (4 cages) as random factor. Slaughter data were subjected to a one way analysis of variance. Fisher LSD multiple range test was used to separate means that were statistically different. The significance level was fixed at 5%. Mortality rate was compared using Pearson's chi-square test (StatSoft, 2012).

RESULTS

The analysed dietary composition (Table 2) fitted well with the expected nutrient composition. Diets had the same CP (15.5%) and NDF (33.7-34.9%) content. The batch of chicory pulp used had a DM content of 10.41% and contained 8.54% CP, 29.64% NDF, 27.13% ADF, 3.71% lignin and 34.0% SF (as fed basis). The content of SF in the experimental diets ranged from 7.3% for the negative control diet to 10% for the SBP and ChP10 diets and to 13.7% for the ChP20 diet (Table 2).

Feed intake and weight gain of rabbits did not differ according to the dietary treatments when the whole period is considered (5 wk of trial) and were rather high: final live weight averaged 2727 g at 67 d of age, corresponding to a daily weight gain of 54.0 g/d and a daily feed intake of 157 g/d (Table 3). Due to this high performance, the trial ceased 1 wk earlier than initially intended.

Only during the first 2 wk of trial, weanlings fed the diet with 20% ChP had a significantly ($P<0.05$) higher daily weight gain and a better feed conversion ratio compared to rabbits fed the NC diet. This difference in feed conversion rate also remained significant when the whole experimental period (5 wk) was taken into account.

At slaughter, no significant differences were recorded for slaughter yield or caecum weight, but a lower liver weight of rabbits fed the SBP diet was determined compared to those fed the control or ChP10 diet (Table 4).

Mortality was low in our trial (2/48 rabbits fed ChP10 diet and 3/48 rabbits fed the other diets) and did not differ ($P>0.10$) according to the experimental treatment. Necroscopy of the dead rabbits revealed pasteurellosis as the main cause.

DISCUSSION

Soluble fibre is known to promote caecal fermentation in fattening rabbits (Falcão-e-Cunha *et al.*, 2004; Gómez-Conde *et al.,* 2009; Xiccato *et al.,* 2011). A sufficient level has been linked with improved digestive health (Gómez-Conde *et al.,* 2007; Gidenne *et al.,* 2010) and especially under epizootic rabbit enteropathy circumstances an increased dietary SF level has been proven to reduce mortality in growing rabbits (Martinez-Vallespin *et al.*, 2011; Trocino *et al.,* 2013). However, although our experimental diets had large differences in SF (from 7.3 till 13.7%), due to the low mortality rate the effect of the SF level on health status could not be confirmed.

In contrast, growth performance and feed intake in the whole trial were not affected by the SF level or source (SBP or ChP), thus confirming the results obtained by Volek and Marounek (2011) who used levels of 5 and 10% chicory

Table 2: Chemical composition (% as fed) and nutritive value of experimental diets.

	Diet			
	NC	SBP	ChP10	ChP20
Dry matter	91.0	92.0	91.1	91.4
Crude protein	15.5	15.6	15.3	15.4
Ether extract	3.3	3.0	3.2	3.3
Crude fibre	16.7	17.7	17.1	17.5
Soluble fibre[1]	7.3	10.6	9.9	13.7
Digestible fibre[2,3]	16.4	21.2	18.7	21.0
Neutral detergent fibre (NDF)	34.9	34.2	33.7	33.9
Acid detergent fibre	18.8	20.2	19.8	21.3
Acid detergent lignin	4.4	4.2	4.2	3.8
Lysine[3]	0.75	0.74	0.75	0.75
Methionine+Cystine[3]	0.59	0.59	0.60	0.59
Digestible Energy[3] (MJ/kg)	9.60	9.65	9.65	9.65

[1] Total dietary fibre–NDF after correction for protein and ash content.

[2] Digestible fibre=hemicellulose+water insoluble pectins (Gidenne, 2003).

[3] Calculated values: Maertens *et al.,* 2002.

Table 3: Effect of soluble fibre source on growth performance of rabbits from weaning (32 d) until slaughter (67 d).

	Diet					
	NC	SBP	CP10	CP20	SEM	*P*-value
Collective cages[1] (No.)	12	12	12	12	-	-
Initial live weight (g)	835	828	844	834	6.5	0.70
Final live weight (g)	2698	2717	2752	2742	15	0.32
Mortality rate (%)	6.3	6.3	4.3	6.3	-	0.82
Daily weight gain (g/d)						
Weeks 1-2	58.7[a]	60.6[ab]	60.3[ab]	63.0[b]	0.5	0.03
Weeks 3-4	52.0	50.7	53.5	49.9	0.6	0.12
Week 5	43.5	45.9	43.2	49.7	0.8	0.17
Weeks 1-5	53.2	53.9	54.4	54.8	0.3	0.11
Daily feed intake (g/d)						
Weeks 1-2	124	125	127	126	1.1	0.70
Weeks 3-4	177	172	175	173	1.4	0.53
Week 5	188	184	182	189	1.9	0.57
Weeks 1-5	158	155	158	158	1.0	0.74
Feed conversion ratio						
Weeks 1-2	2.11[b]	2.06[ab]	2.12[b]	2.01[a]	0.02	0.03
Weeks 3-4	3.40	3.39	3.29	3.48	0.01	0.21
Week 5	4.28	3.94	4.20	3.92	0.07	0.13
Weeks 1-5	2.97[b]	2.88[a]	2.90[ab]	2.88[a]	0.01	0.05

SEM: Standard error of the mean.

[1] Collective cages with 4 rabbits per cage.

[a,b] Means not sharing superscript in the same row are significantly different at $P<0.05$.

root in replacement of oats in their diets. However, an improved feed conversion ratio with the highest level of SF was obtained in our study due to the increased growth rate of young rabbits fed ChP20 diet compared to the control diet, despite the similar feed intake. Accordingly, we could hypothesise that the nutritive value of the ChP20 diet (with the highest level of ChP-SF in replacement of wheat-starch and alfalfa meal-insoluble fibre) was higher than that calculated according to Maertens *et al.* (2002) and that rabbits fed this diet ingested a higher amount of DE during the first 2 wk of trial. In fact, an imperfect regulation of appetite in young rabbits was also reported by other authors (Debray *et al.*, 2002; Trocino *et al.*, 2011). The high DE value of SF-rich diets may depend both on the high digestibility (>0.75) of soluble fibre itself (Grueso *et al.,* 2013) and the characteristics and high digestive utilisation of insoluble fibre contained in these raw materials (Abad *et al.*, 2012).

Table 4: Slaughter results of rabbits at 70 d of age.

	Diet					
	NC	SBP	CP10	CP20	SEM	*P*-value
Rabbits (No.)	10	10	10	10	-	-
Live weight (LW) at slaughter (g)	2893	2881	2978	2858	20.3	0.17
Dressing out percentage (% LW)	55.6	56.5	56.5	56.1	0.24	0.53
Skin (% LW)	15.7	15.8	16.0	15.5	0.20	0.78
Hocks weight (% LW)	2.64	2.65	2.59	2.68	0.04	0.98
Caecum weight (% LW)	7.02	6.65	6.81	7.38	0.19	0.55
Reference carcass (RC) weight (g)	1208	1235	1268	1212	11	0.22
Liver weight (% RC)	7.98[a]	6.71[b]	8.16[a]	7.29[ab]	0.27	0.024
Dissectible fat (% RC)	2.09	2.02	2.29	2.19	0.08	0.61

SEM: Standard error of the mean.

[a,b] Means not sharing superscript in the same row are significantly different at $P<0.05$.

Dried ChP with a level of 27% of pectins and 34% of SF can therefore be considered an energy-rich feedstuff, similarly to SBP (de Blas and Carabaño, 1996), but the energy value that we attributed to ChP (DE: 11.3 MJ/kg) for the calculation of iso-energetic diets seems to be underestimated.

The slaughter data did not reveal any negative consequences on slaughter yield, caecal weight or carcass cuts. This result demonstrates that the increase of dietary SF or the use of a raw material with a high water and liquid absorption capacity (like chicory pulp) does not necessarily modify the gut filling at slaughter age if its use is limited to 20%. Likewise, Trocino *et al.* (2010) found no effect of SBP inclusion rate on slaughter data, using diets with SF levels between 5.5 and 8.5%. However, in other studies (Peeters *et al.,* 1995; Gómez-Conde *et al.*, 2009; Volek and Marounek, 2011) a significant increase was determined in caecal weight when diets with a high SF content were fed. Explanations for this difference could probably be ascribed to the difference in the age of the animals or the fasting period preceding the determination. In the aforementioned studies, rabbits were euthanised for caecal determinations at ages far below normal slaughter age and without a feed deprivation period. Nevertheless, when very high levels (46%) of SBP were used, a greater weight of gut contents was determined and, in consequence, a lower dressing out yield measured (Falcão-e-Cunha *et al.*, 2004).

Falcão-e-Cunha *et al.* (2004) also found a lower liver weight when animals were fed SBP diets, similarly to what we observed in rabbits fed the SBP diet. Accordingly, this effect cannot immediately be ascribed to the increased SF, as it was not observed in rabbits fed ChP10 or ChP20 diets compared to the control diet. Nevertheless, in piglets fed diets containing 5% SBP, a lower liver weight was also observed and related to the higher dietary fibre fractions (Yongxi Ma *et al.*, 2002).

CONCLUSION

Chicory pulp can be considered a rich (34%) SF source which could be used as an alternative to SBP and at inclusion rates up to 20%, with no adverse effects on growth rate, feed intake or slaughter yield and a favourable reduction in feed conversion ratio. Further data on the *in vivo* nutritive value of ChP are necessary to optimise its use in rabbit feeding.

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