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EFFECT OF SUBSTITUTING GUINEA GRASS WITH SUNFLOWER HULLS ON PRODUCTION PERFORMANCE AND DIGESTION TRAITS IN FATTENING RABBITS

LIU G.Y.*†, SUN C.R.*†, ZHAO X.Y.*†, LIU H.L.*†, WU Z.Y.*†, LI F.C.*†

*College of Animal Science and Technology, Shandong Agricultural University, Tai'an 271018, P. R. China.
†Shandong Provincial Key Laboratory of Animal Biotechnology and Disease Control and Prevention, Shandong Agricultural University, Tai'an 271018, P. R. China.

Abstract: The objective of this study was to evaluate the use of sunflower hulls (SH) to substitute guinea grass (GG), traditionally used as a fibre source in the diets of fattening rabbits, on production performance, coefficients of total tract apparent digestibility (CTTAD) of nutrients, gastrointestinal tract development and caecal fermentation. A total of 160 mixed sex Hyla commercial meat rabbits were allocated to 4 experimental groups (40 per treatment) differing in the SH level inclusion in the diet offered to rabbits from 40 to 90 d of age: 0, 30, 60 and 90 g/kg on as-fed basis: SH0, SH30, SH60 and SH90 groups, respectively. Growth performance was recorded from 47 to 90 d of age, CTTAD of nutrients from 86 to 90 d of age, and gastrointestinal tract development, caecal fermentation and carcass traits were determined at 90 d of age. Increasing substitutions of SH in the diet indicated effects on growth performance, as higher feed intake and lower feed efficiency were observed in SH90 compared with SH0 (*P*-linear<0.05). Moreover, the higher SH substitution diet (SH60 and SH90) increased the relative caecum weight (*P*-linear<0.05). A linear negative effect of SH inclusion was observed for the digestibility of neutral detergent fibre (CTTAD from 0.294 to 0.232) and acid detergent fibre (CTTAD from 0.182 to 0.136; *P*-linear<0.05). Dietary SH substitution level had a quadratic effect on the villus height of the duodenum, jejunum and ileum obtained (*P*-quadratic<0.05), and the highest were observed in the SH60 group. There was a quadratic effect on the pH of caecum content (*P*-quadratic<0.05), and the lowest was 6.08 in SH30 group. The total volatil fatty acids increased linearly with increasing SH in diets (from 71.11 to 76.98 mmol/L; *P*-linear<0.05), and when dietary SH increased, the proportion of acetate tended to increase (*P*-linear<0.05), and the proportions of propionic and butyric were decreased (*P*-linear<0.05, respectively). Substitution of GG with SH had no effect on carcass characteristics and meat quality. The current work shows that SH can replace up to 60 g/kg in diets for fattening rabbits, with no adverse impact on aspects of production performance or digestion traits.

Key Words: caecal fermentation, gastrointestinal development, production performance, sunflower hull, rabbit.

INTRODUCTION

The rabbit is a small sized monogastric herbivorous animal and fibre is one of the main constituents of diets for intensively reared rabbits, as the digestive physiology of the rabbit is well adapted to high intake of plant cell walls (De Blas *et al.,* 1999). A minimal concentration of fibre is widely considered the main dietary factor to prevent digestive disorders in fattening rabbits (Gidenne, 2015). Furthermore, dietary fibre is the main constituent of rabbit diet (Gidenne, 2003). Guinea grass (GG) is a widely available forage for ruminant production in most areas of China, and is the main traditional fibre source used in rabbit feeds. However, the price of GG is rising sharply. Alternatives are therefore required to produce balanced pelleted feeds using local raw materials, available at a lower price. Thus, the inclusion of new ingredients in diets that maintain performance as well as keeping costs down is becoming

Correspondence: Li F.C., chlf@sdau.edu.cn. Received *January 2018* - Accepted *April 2018.*
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more important. Sunflower hulls (SH) are one of the by-products of sunflower seed processing, and the price is much cheaper than that of GG in China. SH is a fibrous ingredient with a low energetic value, and SH fibre is characterised by a high amount of acid detergent lignin (ADL) (García *et al.,*1996). Nicodemus *et al.* (2002) reported that SH included at moderate levels (150 g/kg) in the diet of growing rabbits reduced accumulation of digesta in the caecum, which increased voluntary feed intake but impaired growth rate and feed efficiency. SH, as a high dietary ADL concentration, has been related to an impairment of caecal fermentation (García *et al.,*2000a) and to damage of the mucosa (Chiou *et al.,*1994). However, few works have been conducted on the use of SH to substitute GG in fattening rabbit feeding. This study evaluates the use of SH in the diets of fattening rabbits by examining its effect on the production performance, coefficient of total tract apparent digestibility (CTTAD) of nutrients, gastrointestinal tract development and caecal fermentation activity.

MATERIALS AND METHODS

Animals and diets

A total of 160 forty-day-old Hyla commercial meat rabbits (half male and half female) with similar body weights (1309±50 g) were used in this study. All rabbits were randomly divided into 4 groups (n=40, 20 males and 20 females per group) differing in the diet fed during the experiment from 40 to 90 d of age. Rabbits were individually housed in cages (60×40×40 cm). Each cage contained a feeder to provide free access to feed and a nipple drinker to provide free access to water. During the trial, all the rabbits were housed in a closed and ventilated building in which the maximum temperature was 25°C and the minimum temperature was 10°C. A cycle of 12 h of light and 12 h of dark was used throughout this trial.

In the 4 experimental diets, the SH levels (purchased from Tai'an Fortune Sunshine Feed Co. Ltd, China) used in substitution of GG were 0, 30, 60 and 90 g/kg on as-fed basis (groups SH0, SH30, SH60 and SH90, respectively). The chemical composition of SH and GG hay are shown in Table 1. The diets (Table 2) were formulated according to the values from NRC (1977). The 4 diets were passed through a roller mill prior to being mixed and pelletised (3-4 mm in diameter and 10-15 mm in length), and stored in the dark.

Experimental procedures

The experimental procedures were approved by the Committee of Ethics in Research of Shandong Agricultural University and performed in accordance with the Guidelines for Experimental Animals of the Ministry of Science and Technology (Beijing, China). The feed was offered *ad libitum*. The total experiment consisted of a 7-d adjustment period followed by a 43-d experimental period, including a 4 d period (day 86 to day 90) for faeces collection.

Individual weight was measured at the beginning and end of the trial and the average daily gain (ADG) calculated. The average daily feed intake (ADFI) was calculated according to total feed intake divided by total experimental days. The feed conversion ratio (FCR) was then calculated as kg feed intake/kg weight gain. The ADG, ADFI and FCR calculations did not include the 7-d adaptation period.

The CTTAD of nutrients was measured in an *in vivo* digestibility assay carried out on 32 rabbits: 8 animals of both sexes per diet chosen as representative of the live weight, mean and variability within groups. Following a 3-d period of adaptation to metabolism cages, the feed intake (*ad libitum* access) and total faecal output (caecotrophy was not prevented) were recorded for each rabbit over a 4-d period. The digestibility trial lasted from 86 to 90 d of age to

Table 1: Chemical composition of sunflower hull and guinea grass (g/kg, as-fed basis).

Items	GE (MJ/kg)	DM	CP	EE	NDF	ADF	ADL	Ash
Sunflower hull	19.63	903	29.9	37.4	787	459	165	39.9
Guinea grass hay	15.95	862	84.6	10.6	472	385	57	72.3

GE, gross energy; DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin.

Table 2: Ingredient of the experimental diets and chemical analysis (g/kg, as-fed basis).

Items	Group			
	SH0	SH30	SH60	SH90
Ingredients				
Corn	200	200	200	200
Soybean meal	200	200	200	200
Wheat bran	100	100	100	100
Wheat middling	125	125	125	125
Alfalfa hay	50	50	50	50
Beanstalk	50	50	50	50
Rice hull	50	50	50	50
Guinea grass hay	200	170	140	110
Sunflower hull	0	30	60	90
$CaHPO_4$	10	10	10	10
Salt	5	5	5	5
Premix [1]	10	10	10	10
Energy and chemical composition [2]				
GE (MJ/kg)	16.43	16.35	16.33	16.14
DM	900	902	904	905
CP	163	161	159	157
EE	21.1	22.0	23.2	24.1
NDF	351	361	370	389
ADF	202	204	205	206
ADL	35	37	39	42
Ash	98.7	97.0	96.2	95.3

GE, gross energy; DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin.

[1] The premix provides the following per kilogram of diet: vitamin A 8000 IU; vitamin D_3 31,000 IU; vitamin E 50 mg; Lysine 1.5 g; Methionine 1.5 g; Cu (as copper sulphate) 50 mg; Fe (as ferrous sulphate) 100 mg; Mn (as manganese sulphate) 30 mg; Mg (as magnesium sulphate) 150 mg; I (as potassium iodide) 0.1 mg; Se (as sodium selenite) 0.1 mg.

[2] Measured values.

determine the CTTAD of dry matter (DM), gross energy (GE), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF), acid detergent fibre (ADF) and ADL of the diets.

At the end of the digestibility trial (90 d), the 32 rabbits were weighed (slaughter weight: SW) and measured (body length: BL) before slaughtering (8:00 in the morning). After bleeding, the pelts, paws and full contents were removed and the hot carcasses were weighed after slaughter to calculate the dressing percentage. Dressing percentage=100×hot carcass weight/slaughter weight. Carcasses were chilled at +4°C and after 24 h were weighed. At 24 h drip loss (%)=(hot carcass weight–chilled carcass weight)/hot carcass weight (%). The stomach, small intestine and caecum were removed immediately and weighed before and after emptying their contents. The pH in caecum was immediately measured. A sample of caecal content (200 mg) was diluted with a 1 mL 15% HPO_3 solution and stored at –20°C pending chemical analysis. In addition, the length of the small intestine was measured.

Meanwhile, the whole *Longissimus lumborum* (LL; between the 1st and 7th lumber vertebra) was removed from the right side of each carcass. The LL was then divided into 3 sub-samples. One sub-sample was used for pH measurements at 45 min and 24 h. The muscle colour (L^*, a^* and b^*) and shear force were determined at the end of the chilling period (24 h) on the second and third sub-samples, respectively. Shear force (kg·f) was measured in triplicate using the Warner-Blatzler meat shear apparatus (C-LM, USA). Each sample were cores (Φ=1.25 cm, thickness=2 cm) obtained from LL samples, cut perpendicularly to the fibre direction and previously cooked in a water bath (80°C, 10 min).

Chemical analyses

The Association of Official Analytical Chemists (AOAC) International (2005) procedures were used to determine the content of DM (934.01), CP (954.01) and ash (942.05) in SH, GG, feeds and faeces. CP content (6.25×N) and EE were determined using a Kjeltec Auto 1030 Analyser and a Soxtec 1043, respectively (FOSS Tecator AB, Höganäs, Sweden). Analysis of fibre components was performed according to Goering and Van Soest (1970), except NDF (Van Soest *et al.,* 1991). NDF was assayed with a heat stable amylase and expressed as exclusive of residual ash (NDFom); ADF was expressed as exclusive of residual ash (ADFom); ADL was determined by solubilisation of cellulose with sulphuric acid. The energy levels of the SH, GG, feed and faeces were measured by bomb calorimetry (Parr 6300 Calorimeter, Moline, IL, USA).

The duodenum, jejunum and ileum tissue samples for light microscopy were prepared according to the method of Xu *et al.* (2003) and modified as follows: the 3 cm segments of duodenum, jejunum and ileum were cut longitudinally at the mesenteric attachment and immediately fixed in 10% neutral formalin. The samples were then dehydrated in graded alcohols, cleared with xylene and embedded in paraffin. The serial microtome sections (6 µm thick) were stained with haematoxylin and eosin stain. The villus height and crypt depth of 10 slices of every tissue sample at 40× magnification under light microscope were measured and the ratio of villus height/crypt depth ratio was calculated.

The pH value of caecal content was determined from each rabbit 45 min post-mortem using a pH meter equipped with a pH probe (Crison MicropH 2001). The thawed samples of caecal contents were then centrifuged at 2500 *g* at 0°C for 10 min. The ammonia nitrogen and volatile fatty acid (VFA) concentrations were measured in the supernatant. The ammonia nitrogen concentration was measured using a spectrophotometer according to Weatherburn (1967). VFA concentration in the supernatant was measured by gas chromatography (Fisons 8000 series, Milan, Italy) equipped with an AS800 automatic injector. The column used was a BD-FFAP 30 m×0.25 mm×0.25 µm. Injector and detector temperatures were maintained at 250°C, and the oven temperature was set to 150°C.

Statistical analysis

The experiment was conducted using a completely randomised design (4 treatments, 40 replicates/treatment and one rabbit per replicate). Data on growth performance (n=40/treatment), CTTAD, gastrointestinal tract development, caecal fermentation and carcass traits and meat qualities (n=8/treatment) were analysed by ANOVA in a completely randomised design using the GLM procedure of SAS (SAS Inst., Cary, NC, USA). The orthogonal polynomial contrast test was performed to determine linear and quadratic effect of inclusion level of SH in diets. Differences among treatments were considered statistically significant if $P<0.05$.

RESULTS AND DISCUSSION

Health condition and growth performance

During the trial no deaths occurred, and no rabbit displayed feed intake reduction, weight loss or disease. ADFI and FCR increased significantly as SH level increased, and a higher feed intake and FCR were observed in SH90 compared with SH0 (*P*-linear=0.023 and *P*-linear=0.045, respectively). However, no significant differences in linear or quadratic effects were observed for ADG (Table 3).

Dietary fibre has been known to affect rabbit performance, but the effects are largely dependent on the source of fibre, due to its highly variable lignification and cell wall complexity and different hemicellulose constituents (Gidenne, 1992; Carabaño *et al.,* 2001; García *et al.,* 2002b). Of course, the main constituent of SH is fibre (NDF>78%), and ADL was higher in SH than GG (165 *vs.* 56.5 g ADL/kg in SH and GG, respectively; Table 1). Nicodemus *et al.* (2002) reported that SH included at moderate levels (150 g/kg) in the diet of growing rabbit increased voluntary feed intake but impaired growth rate and feed efficiency. In the present study, the higher feed intake is due to the increased fibre content of the SH inclusion and the lower DE of the SH diets (9.43 *vs.* 8.88 MJ/kg DE in SH0 and SH90, respectively; Table 4). Besides, the substitution level of SH in the diets did not affect ADG from 47 to 90 d of age, and there were no health problems associated with the dietary treatments or diseases during the trial. A similar effect was previously observed in broilers (Karunajeewa *et al.,*1989; Arija *et al.,*1998).

Table 3: Growth performance of experimental rabbits from 47 day until 90 day (n=40).

	Group					*P*-Value	
Items	SH0	SH30	SH60	SH90	RMSE	Linear	Quadratic
IBW (g)	1546	1559	1510	1571	193.0	0.541	0.433
ADFI (g/d)	144.8^{a}	146.9^{ab}	148.4^{ab}	151.1^{b}	11.05	0.023	0.242
ADG (g/d)	32.9	32.3	32.1	30.2	7.75	0.606	0.880
FCR	4.40^{a}	4.55^{ab}	4.62^{ab}	4.98^{b}	0.632	0.045	0.502

Different letters denote significant ($P<0.05$). RMSE, root mean square error; IBW, initial body weight; ADFI, average daily feed intake; ADG, average daily gain; FCR, feed conversion ratio.

CTTAD of nutrients in experimental diets

A linear negative effect of SH inclusion was observed for the digestibility of NDF (CTTAD from 0.294 to 0.232; *P*-linear=0.0014) and ADF (CTTAD from 0.182 to 0.136; *P*-linear=0.0201). The digestibility of DM, GE, CP and EE was similar in all 4 groups (Table 4).

Fibre source has an important role in regulation of the intestinal transit, gut flora and the intestinal mucosa integrity of rabbits (De Blas *et al.,* 1999; Fortun-Lamothe and Boullier, 2007) and it has been observed that the digestibility of DM, organic matter, CP, EE, NDF, ADF and energy is affected by the source of fibre. The improvement in the nutrient apparent digestibility and the nutritive value of diets with decreasing NDF is well established (Gidenne and Bellier, 2000; Xiccato *et al.,* 2002). In our study, we observed that higher SH inclusion in diet impaired digestibility of NDF and ADF. This might be due to the higher ADL in diets with increasing SH level (35, 37, 39 and 42 g ADL/kg in SH0, SH30, SH60 and SH90 group, respectively; Table 2). The high lignin content makes SH hardly digestible by animals.

Gastrointestinal tract development

Table 5 shows the effect of different SH dietary treatments on gastrointestinal tract development. There were no linear or quadratic effect variations in the relative weight (g/kg SW) of stomach, small intestine and their contents. Moreover, the relative lengths of small intestine (/Body length) were not linearly or quadratically affected by SH. However, the relative weight of caecum increased with the increase in SH level (*P*-linear=0.0473).

The intake of high-fibre diets can cause a significant extension of the gastrointestinal tract, with an additional increase in length. The level and type of dietary fibre can play the most important role in controlling gastrointestinal tract development and digestive content (Margüenda *et al.,* 2012). Dietary fibre affects feed intake and the retention time of content in the caecum (De Blas *et al.,* 1999; García *et al.,* 1999, 2002b). At the same level of fibre, the inclusion

Table 4: Coefficient of total tract apparent digestibility of nutrients and nutritive values in experimental diets (n=8).

	Group					*P*-Value	
Items	SH0	SH30	SH60	SH90	RMSE	Linear	Quadratic
Digestibility coefficients							
DM	0.526	0.563	0.534	0.550	0.048	0.6376	0.3465
GE	0.574	0.576	0.534	0.550	0.029	0.6852	0.4527
CP	0.733	0.759	0.740	0.728	0.032	0.5398	0.1079
EE	0.860	0.857	0.829	0.803	0.055	0.1800	0.4044
NDF	0.294^{b}	0.285^{b}	0.252^{ab}	0.232^{a}	0.067	0.0014	0.7818
ADF	0.182^{b}	0.168^{ab}	0.165^{ab}	0.136^{a}	0.052	0.0201	0.5823
Diet nutritive values							
DE (MJ/kg, as-fed basis)	9.43	9.42	8.72	8.88			
DP (g/kg, as-fed basis)	119	122	118	114			
DP to DE ratio (g/MJ)	12.62	12.95	13.53	12.84			

Different letters denote significant ($P<0.05$). RMSE, root mean square error. GE, gross energy; DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; ADF, acid detergent fibre; DE, digestible energy; DP, digestible protein.

Table 5: Gastrointestinal tract development of experimental rabbits (n=8).

	Group					*P*-Value	
Items	SH0	SH30	SH60	SH90	RMSE	Linear	Quadratic
Stomach relative weight (g/kg SW)	12.02	13.04	13.35	13.38	1.372	0.2983	0.3183
Stomach content relative weight (g/kg SW)	41.63	43.69	50.60	49.99	8.562	0.1910	0.6621
Small intestine relative length (BL)	9.53	9.56	9.85	10.20	1.134	0.5658	0.2473
Small intestine relative weight (g/kg SW)	29.22	29.69	29.30	30.99	3.492	0.3833	0.6257
Small intestine content relative weight (g/kg SW)	7.66	8.36	9.54	9.62	2.921	0.6850	0.7064
Caecum relative weight (g/kg SW)	13.80^{a}	14.29^{a}	15.99^{b}	15.05^{b}	1.011	0.0473	0.0567
Caecum content relative weight (g/kg SW)	44.17	44.98	43.76	44.50	8.634	0.9861	0.9906

Different letters denote significant (P<0.05). RMSE, root mean square error; SW, slaughter weight; BL, body length.

of lignified fibre decreased retention time of the digesta in the stomach and caecum and decreased overall weight of stomach and caecum (Gidenne and Perez, 1994; García *et al.,* 2002a; Nicodemus *et al.,* 2002). Jehl and Gidenne (1996) pointed out that the caecal weight is related to ADFI. In our study, the relative weight of caecum with increased level of SH, probably in relation with increasing ADFI level (Table 3).

Histological evaluation of the small intestine

Table 6 presents the histological evaluation of the small intestine of the experimental rabbits. Dietary SH substitution level had a quadratic effect on the villus height of the duodenum, jejunum and ileum obtained (P-quadratic<0.0001), and the highest were observed in SH60 group. Besides, the villus height/crypt depth ratios of the duodenum, jejunum and ileum up to the maximum were found in SH30, SH60 and SH60 group, respectively.

Yu and Chiou (1996) observed slight changes in jejunal villus in growing rabbits fed from 55 to 145 g/kg levels of crude fibre. Chiou *et al.* (1994) observed that different fibre components influenced villus height and muscle layer thickness of the jejunum and colon, and affected the crypt depth of the duodenum and ileum of domestic rabbits. Xiccato *et al.* (2008) did not detect differences in villi length or crypt depth according to dietary high-digestible fibre/starch ratio. In the present study, the use of 90 g/kg SH in substitution for GG could impair the villus height in the small intestine.

Caecal fermentation activity

The values of caecal pH, ammonia nitrogen and total VFA concentrations and individual proportions are reported in Table 7. There were no linear or quadratic effects on the production of ammonia nitrogen, while there was a

Table 6: Histological evaluation of the small intestine in experimental rabbits (n=8).

	Group					*P*-Value	
Items	SH0	SH30	SH60	SH90	RMSE	Linear	Quadratic
Duodenum							
Villus height /(μm)	703.2^{a}	867.4^{b}	854.9^{b}	732.1^{a}	128.3	0.5858	<0.0001
Crypt depth /(μm)	110.1	103.4	106.1	104.4	20.2	0.6201	0.6924
Villus height/Crypt depth	6.38^{a}	8.39^{b}	8.06^{b}	7.01^{ab}	1.223	0.2344	<0.0001
Jejunum							
Villus height /(μm)	743.1^{a}	961.3^{ab}	1176.5^{b}	791.5^{a}	163.5	0.0911	<0.0001
Crypt depth /(μm)	126.9	125.9	115.8	117.3	25.4	0.2433	0.8617
Villus height/Crypt depth	5.86^{a}	7.64^{ab}	10.15^{b}	6.74^{ab}	1.37	0.0047	<0.0001
Ileum							
Villus height /(μm)	540.6^{a}	617.5^{ab}	728.5^{b}	498.7^{a}	74.4	0.8707	<0.0001
Crypt depth /(μm)	123.6	127.8	111.4	123.4	23.5	0.5305	0.5366
Villus height/Crypt depth	4.24^{a}	4.99^{ab}	6.54^{b}	4.04^{a}	0.705	0.2426	<0.0001

Different letters denote significant (P<0.05). RMSE, root mean square error.

Table 7: Caecal fermentation activity of experimental rabbits (n=8).

	Group					*P*-Value	
Items	SH0	SH30	SH60	SH90	RMSE	Linear	Quadratic
Caecal content pH	6.41[b]	6.08[a]	6.14[a]	6.26[ab]	0.196	0.2182	0.0032
Ammonia nitrogen (mmol/L)	36.37	44.63	40.32	44.40	15.17	0.3576	0.4316
Total VFA (mmol/L)	71.11[a]	74.77[b]	76.24[b]	76.98[b]	3.787	0.0460	0.2940
Acetic (mmol/100 mmol VFA)	78.46[a]	83.51[ab]	85.22[b]	86.56[b]	6.718	0.0088	0.8173
Propionic (mmol/100 mmol VFA)	8.08[b]	7.07[b]	5.84[a]	5.07[a]	1.812	0.0031	0.2091
Butyric (mmol/100 mmol VFA)	16.31[b]	14.86[ab]	12.53[ab]	9.71[a]	5.112	0.0132	0.7116

Different letters denote significant ($P<0.05$). RMSE, root mean square error; VFA, volatile fatty acids.

quadratic effect on the pH of caecum content (*P*-quadratic=0.0032), and the lowest was 6.08 in the SH30 group. The total VFAs increased linearly with increasing SH level in diets (from 71.11 to 76.98 mmol/L; *P*-linear=0.0460), and when dietary SH increased, the proportion of acetate tended to increase (*P*-linear=0.0088), while the proportions of propionic and butyric were decreased (*P*-linear=0.0031 and *P*-linear=0.0132, respectively).

Carabaño *et al.* (2009) found that increased availability of a fermentable substrate could decrease the utilisation of protein for energy purposes while promoting microbial protein synthesis, thus reducing the ammoniacal nitrogen level in the caecum. In the present trial, the concentration of ammoniacal nitrogen in the caecal content was not linearly or quadratically affected by dietary SH. Both VFA levels and the pH of caecal contents, which can be taken as indicators of fermentative activity, change according to the nature of the fibre ingested. VFAs are the end products of microbial fermentation (Bellier and Gidenne, 1996), playing an important role in the aetiology of digestive disturbances (Gidenne, 1997), and their levels are lower with high lignin fibre and higher with high pectin fibre (García *et al.,* 2000), with the latter also having the tendency to decrease the pH of caecal contents (García *et al.,* 2002b). Meanwhile, Bellier and Gidenne (1996) found an increase of VFA concentration in caecum of rabbits fed a high-fibre diet. García *et al.* (2002b) reported that acetate increased and butyrate decreased when increasing dietary NDF, whereas propionate was positively correlated with the dietary content in uronic acids. In the present work, the production of acetic increased with increasing SH inclusion level, which might be due to the increasing level of NDF, as shown in Table 2 (351, 361, 370 and 389 g NDF/kg in SH0, SH30, SH60 and SH90 group, respectively). García *et al.* (2002a) showed that caecal pH is negatively related to dietary digestible NDF concentrations. Besides, lower pH were associated with higher total VFA concentration, while VFA are the main source of H^+ in the caecal contents (De Blas *et al.,* 1999). Thus, the higher NDF level in SH than GG (787 *vs.* 472 g NDF/kg in SH and GG, respectively; Table 1) should explain the caecal pH values in this study.

Table 8: Carcass traits and meat qualities of experimental rabbits (n=8).

	Group					*P*-Value	
Items	SH0	SH30	SH60	SH90	RMSE	Linear	Quadratic
Carcass traits							
Slaughter weight (g)	2956	2948	2890	2871	120.0	0.1078	0.9010
Hot carcass weight (g)	1526	1499	1495	1486	77.7	0.6649	0.7523
Dressing percentage (%)	51.6	50.9	51.7	51.8	1.59	0.1433	0.7808
24 h Drip loss (%)	9.3	9.0	9.2	9.8	2.42	0.1132	0.9879
LL characteristics							
pH (45 min)	6.68	6.66	6.71	6.63	0.128	0.6246	0.4137
pH (24 h)	5.60	5.59	5.65	5.59	0.075	0.6374	0.1665
Shear force (kg.f)	2.53	2.54	2.55	2.50	0.176	0.9156	0.6363
L*	32.65	35.83	34.68	34.44	2.676	0.2674	0.8290
a*	32.74	32.74	32.78	31.26	3.070	0.8066	0.2456
b*	8.14	7.48	8.75	8.23	1.436	0.5340	0.2606

RMSE, root mean square error; LL, *Longissimus lumborum;* L*, lightness; a*, redness; b*, yellowness.

Carcass traits and meat qualities

The hot carcass weight, dressing percentage and 24 h drip loss were similar among the 4 groups. Likewise, the pH (45 min), pH (24 h), shear force and sensory traits (L*, a*, b*) of LL muscles were not affected by the inclusion of SH in the diet (Table 8).

The effect of diet composition on carcass and meat quality has been a matter of some investigation. In order to find less expensive raw materials and alternatives to cereal grains, some fibre sources, such as sugar beet pulp (García *et al.,* 1993; Margüenda *et al.,* 2012) or olive pomaces (Bosco *et al.,* 2012), have been tested at different levels of inclusion. All these studies found that the lower levels (5 to 15%) of supplementation showed little or no positive effects on growth performance, dressing percentage or meat characteristics such as tenderness, drip loss and colour. Our results are not surprising, as feeding treatments hardly affect slaughter results and carcass characteristics or meat traits, if animals fed *ad libitum* balanced diets and with minor differences in final body weight are recorded (Xiccato, 1999; Hernández, 2008).

CONCLUSION

For fattening rabbits, the use of 60 g/kg SH in substitution for GG (DE 8.72 MJ/kg, DP 118 g/kg, DP to DE ratio 13.53 g/MJ; as-fed basis) has no adverse effects on the growth performance, carcass traits and meat qualities, CTTAD of nutrients, gastrointestinal tract development and caecal fermentation. SH could thus be considered as an interesting fibre source for the fattening rabbit, which has a low level of soluble and/or fermentable fibre content. However, SH has a lower DE content than GG, which leads to a higher feed intake and impaired feed efficiency.

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