Effect of Inclusion of Hard Versus Soft Wheat Bran with Different Particle Size on Diet Digestibility, Growth Performance and Carcass Traits of Fattening Rabbits

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ABSTRACT : Effect of inclusion of hard vs. soft wheat bran with different particle size on diet digestibility, growth performance and some slaughter traits was evaluated in fattening rabbits. Four isonitrogenous and isocaloric diets were used according to the origin of wheat bran (hard (HWB) - *Triticum durum* - and soft (SWB) - *Triticum aestivum*) combined with wheat bran particle size sieved by 2 mm (fine: 2) or by 8 mm (coarse: 8) in a bifactorial (2×2) study. A growth trial was conducted to measure the effect of treatments on performance in one hundred and twenty New Zealand White×Californian rabbits fed experimental diets from 50 to 87 days of age. Faecal apparent digestibility was determined within the last week in twenty animals per diet. Digestibility of nutrients was higher (p<0.05) in the diet containing HWB2, except for crude protein, ether extract and ash, than fine and coarse soft wheat bran diets. Final live weight, feed intake and feed consumption of rabbits on the diet with fine hard wheat bran were higher and resulted in greater daily weight gains (p<0.01) than for animals on the other diets. The slaughter yield and percentage value of organs were not significantly (p>0.05) affected by the diets fed; however, the diet containing fine hard wheat bran led to lower (p<0.05) percentages of skin, abdominal fat and carcass drip loss than the other dietary treatments. It is concluded that fine hard wheat bran can be better included in the diet than soft wheat bran to maximize growth performance without affecting carcass traits of fattening rabbits. (**Key Words :** Rabbit, Wheat Bran, Digestibility, Particle Size, Carcass Traits)

INTRODUCTION

In the European Union (EU), France has the highest volume of wheat production followed by Germany and the United Kingdom. Italy has the highest rate of wheat usage for human nutrition, followed by the United Kingdom and France which have the highest rate of wheat usage as animal feed. Hard wheat production of the EU is concentrated in Southern Europe. Italy has the highest durum wheat production followed by France and Greece. Hard wheat traditionally accounts for 23% of total EU wheat production. In the last decade, wheat by-products have shown a steady increase with a good amount for export. The hard wheat division is strategic in the EU

agroindustry picture because it represents the basis of the milling industry.

There are wheat classes based on hardness, colour (red or white), lifestyle (spring or winter) or even production site. The common wheat (*Triticum aestivum*) has cultivars differing in hardness, e.g. hard wheat: cv. Tiger and soft wheat: cv. Crousty, but also the genetically different hard durum wheat (*Triticum durum*). There are variations in wheat grain tissue proportions (outer layer, aleurone, endosperm, germ) which differ in starch, proteins, minerals, vitamins, etc. When milling, the extraction rate influences the quality of the flour or the bran (for example, nutrient digestibility is higher in bran fractions rich in aleurone than in fractions rich in outer pericarp). Moreover, hardness affects the milling result. In modern roller milling the by-products of wheat are usually sold as three separate products obtained at different stages of the process (successive sieving): germ, fine and coarse wheat bran. Most of the literature indicates that fine bran is characterised by a higher endosperm/bran ratio than coarse

bran (Blas et al., 2000).

Traditionally, by-products of wheat from the milling industry have been standardised in every country: wheat bran, wheat middlings and wheat feed, for products varying in their crude fibre contents. However, the different objectives and technologies used by millers lead to the supply of many products with the generic name wheat bran that could have various contents of endosperm and, consequently, could be different from the standard product (Blas et al., 2000). Moreover, two types of wheat bran are usually obtained at different stages of milling at present: coarse wheat bran (6-8 mm), obtained during the initial stages of sieving, and fine wheat bran (2-3 mm), which is characterised by smaller size, obtained during the final stages of sieving.

The nutritional value of wheat bran and its inclusion in diets as a fibrous source for rabbits, has been evaluated in experimental studies (Fernandez-Carmona et al., 1996; Lakabi-Ioualitene et al., 2008) which are inconsistent, showing great variability in chemical and digestible composition, probably due to the different products studied. Dietary fibre is necessary for rabbits to maintain a high rate of passage, avoiding an accumulation of digesta in the caecum that reduces feed intake and impairs growth (De Blas et al., 1999). Type of fibre is also important, as chemical composition and physical structure of plant cell walls vary widely among fibre sources. Nicodemus et al. (2006) determined a minimal dietary acid detergent lignin (ADL) concentration of 4.1 g/kg DM for fattening rabbits. Lower dietary ADL concentrations led to an accumulation of digesta in the caecum which reduced feed intake, growth and increased mortality during fattening (Nicodemus et al., 2006). Moreover, physical structure, especially particle size, is another important characteristic of fibre that influences its digestive behaviour in rabbits. Rabbits have a digesta separation mechanism in the colon which results in selective retention of fluid and fine feed particles in the caecum (Sakaguchi et al., 1992). The low digestibility of fibre in the rabbit seems to be related to this digestive strategy which results in the relatively rapid elimination of large particles, enabling the animal to maintain a higher level of feed intake than it would otherwise be able to. The reduction of dietary particle size by finely grinding the diet has produced variable results (Gomes et al., 2000; Lambertini et al., 2000; Nicodemus et al., 2006). In commercial practice, it is recommended to use sieves with a diameter not smaller than 2-2.5 mm (Lebas, 2000). Nevertheless, in a review Gidenne (2000) showed that feed particle size has been little studied in rabbit nutrition, and current data in the literature are conflicting.

The most common ingredient used to meet fibre requirements is soft wheat bran which, on average, usually accounts for one fourth of the diet. When the price,

availability and/or quality of soft wheat demand its substitution, other fibrous sources such as hard wheat have to supply neutral detergent fibre (NDF) and ADL. Therefore, the aim of this study was to evaluate the effect of added hard or soft wheat bran combined with different particle size (fine and coarse) in diets for fattening rabbits on nutrient digestibility, growth and slaughter performances.

MATERIALS AND METHODS

Diets

Four experimental diets were factorially (2×2) arranged with two types of wheat bran, from hard (*T. durum*) and soft (*T. aestivum*) wheat, and two wheat bran particle sizes (fine and coarse). The particle sizes of wheat bran were: fine texture for hard wheat bran sieved by 2 mm (HWB2), coarse texture for hard wheat bran sieved by 8 mm (HWB8), fine texture for soft wheat bran sieved by 2 mm (SWB2) and coarse texture for soft wheat bran sieved by 8 mm (SWB2). To produce fine and coarse particles, hard and soft wheat bran were ground using a hammer mill to which 2, 3, 6 and 8 mm sieves were attached. The diets were formulated to be isonitrogenous and isocaloric and to meet or exceed the nutrient requirements of growing rabbits (De Blas and Mateos, 1998). The other feedstuffs in all diets were ground using a hammer mill to pass only a 5 mm sieve. All ingredients were homogeneously mixed with a feed mixer equipped with a hammer mill. Diets were prepared in pelleted form. The ingredient composition and chemical analysis of hard and soft wheat bran and the diets is shown in Table 1. Five samples of each batch of complete diet after the homogenous mixing were taken for the measurement of feed particle size distribution. This was determined by passing each sample through a series of laboratory sieves and weighing the amount collected on each screen and on the pan under the 2 mm screen (Table 2). The diets did not contain any supplementation of coccidiostat.

Animals and housing

The study was carried out in an experimental rabbitry located in Southern Italy in the Campania region, according to the guidelines for applied nutrition experiments in rabbits (Fernández-Carmona et al., 2005). One hundred and twenty New Zealand White×Californian rabbits aged 50 days, weaned at 35 days of age and weighing on average 1,300±31 g, were randomly assigned to four groups of thirty animals (fifteen male and fifteen female rabbits each). The animals were housed individually under standard conditions between 15 and 23°C, controlled by heating and forced ventilation systems, in wire cages measuring 360× 450×310 mm and at a height of 90 cm from the concrete floor. A cycle of 12-h of light and 12-h of dark was used throughout the experiment. The light was switched on at

Table 1. Ingredients and chemical composition (as-fed) of the experimental diets

	Hard wheat bran	Soft wheat bran	Diet[a]			
			HWB2	HWB8	SWB2	SWB8
Ingredients (%)						
Dehydrated alfalfa meal			32.00	32.00	32.00	32.00
Hard wheat bran			22.75	22.75	-	-
Soft wheat bran			-	-	25.00	25.00
Barley			14.00	14.00	14.00	14.00
Soybean hull			10.00	10.00	10.00	10.00
Corn			7.00	7.00	7.00	7.00
Soybean meal, 44% CP			3.00	3.00	3.00	3.00
Sunflower meal, 36% CP			2.85	2.85	2.85	2.85
Hard wheat flour			2.25	2.25	-	-
Carob pulp			2.00	2.00	2.00	2.00
Cane molasses			1.00	1.00	1.00	1.00
Vitamin-mineral premix [b]			0.50	0.50	0.50	0.50
Sodium chloride			0.50	0.50	0.50	0.50
Monocalcium phosphate			0.50	0.50	0.50	0.50
Calcium formate			0.40	0.40	0.40	0.40
DL-methionine			0.25	0.25	0.25	0.25
Calcium carbonate			0.25	0.25	0.25	0.25
Yeast			0.20	0.20	0.20	0.20
Magnesium carbonate			0.10	0.10	0.10	0.10
L-lysine			0.05	0.05	0.05	0.05
Chemical composition (g/kg)						
Dry matter	86.49	85.89	87.52	87.64	87.04	87.23
Organic matter	95.81	96.34	92.81	92.66	92.49	92.57
Crude protein	13.38	13.79	15.18	15.03	15.21	15.12
Ether extract	3.37	3.54	2.51	2.67	2.59	2.41
Starch	20.36	22.54	13.61	13.79	13.72	13.89
Crude fibre	9.86	8.61	14.21	14.06	14.34	14.26
Crude ash	4.19	4.49	7.19	7.34	7.51	7.43
Neutral detergent fibre	20.36	22.64	27.74	27.96	28.37	28.16
Acid detergent fibre	28.81	30.33	17.61	17.47	17.81	17.69
Acid detergent lignin	10.65	13.31	4.67	4.51	4.93	4.87
Acid insoluble ash	2.86	3.66	0.74	0.81	1.11	1.06
Hemicellulose	18.16	17.02	10.49	10.13	10.47	10.56
Cellulose	7.79	9.65	12.96	12.94	12.82	12.88
Digestible energy (MJ/kg)[c]	16.74	16.61	10.4	10.5	10.4	10.5

[a] HWB2 = Diet containing hard wheat bran sieved by 2 mm; HWB8 = Diet containing hard wheat bran sieved by 8 mm; SWB2 = Diet containing soft wheat bran sieved by 2 mm; SWB8 = Diet containing soft wheat bran sieved by 8 mm.

[b] Provided per kg of diet: vitamin A 12,500 IU; vitamin D_3 1,500 IU; vitamin E 30 mg; vitamin B_1 1.5 mg; vitamin B_2 5 mg; vitamin B_6 2 mg; vitamin B_{12} 0.02 mg; vitamin PP 20 mg; vitamin K_3 2.5 mg; folic acid 0.75 mg; pantothenic acid 10 mg; D-biotin 0.1 mg; choline chloride 300 mg; $MnSO_4$ 150 mg; $FeSO_4$ 5 mg; $ZnSO_3$ 75 mg; $CuSO_4$ 5 mg; KI 1 mg; $CoSO_4$ 0.2 mg; Na_2SeO_3 0.1 mg.

[c] Calculated according to regression proposed by Fernandez-Carmona et al. (1996).

07.30 am. Rabbits were fed *ad libitum* and water was available from nipple drinkers.

Digestibility trial

The apparent digestibility of the four diets was determined at 77 days of age according to the European reference method (Perez et al., 1995). A group of sixty New Zealand White×Californian finishing rabbits (15/treatment) were selected at random to determine the apparent faecal digestibility of nutrients. The faeces were collected using a

Table 2. Mean particle size composition of diets (g/kg DM) containing fine (2 mm) or coarse (8 mm) wheat bran

	Particle size (mm)				
	<2	2-4	4-6	6-8	>8
Diet[a]					
HWB2	342.7	615.4	33.4	8.1	0.4
HWB8	26.9	92.1	401.4	451.5	28.1
SWB2	395.1	572.7	21.1	10.4	0.7
SWB8	35.8	125.3	362.5	441.6	34.8

[a] HWB2 = Diet containing hard wheat bran sieved by 2 mm; HWB8 = Diet containing hard wheat bran sieved by 8 mm; SWB2 = Diet containing soft wheat bran sieved by 2 mm; SWB8 = Diet containing soft wheat bran sieved by 8 mm.

nylon net placed under the cages of each treatment, to avoid urine contamination. Each pooled faecal sample was taken and placed in a two-layer plastic bag to prevent the loss of moisture and immediately frozen at -20°C. The frozen samples were individually mixed thoroughly and pooled, ground in a homogenizer (Tecator, Herndon, VA, USA) and representative samples were then weighed on an aluminium foil pan, dried in a draft oven at 80°C to constant weight and stored for chemical analysis.

The digestibility coefficients were calculated following the indirect digestibility method (Furuichi and Takahashi, 1981) using acid insoluble ash (AIA) as an inert marker. The calculation of the digestibility of dry matter was as follows: Dry Matter digestibility (%) = $(1-A/B) \times 100$, where A and B are the acid insoluble ash concentrations in the feed and faeces, respectively. The digestibility of the other nutrients (X) was calculated as follows: Digestibility (X in %) = $(1-A/B \times XB/XA) \times 100$, where XA and XB are the concentrations of X in the feed and faeces, respectively.

Analytical methods

Samples of compound feeds and dry faeces were ground in a hammer mill provided with a 1 mm pore size screen and analysed in duplicate for chemical composition. Chemical analysis of diets and faeces was made using the method of Van Soest et al. (1991) for NDF and the official method (973.18) of the Association of Official Analytical Chemists International (2000) for acid detergent fibre (ADF) and acid detergent lignin (ADL). Neutral detergent fibre was determined directly and corrected for its ash content, whereas ADF and ADL were extracted successively and corrected for the ash content of ADL residue. Hemicellulose and cellulose were also estimated as NDF (ash free)-ADF (ash free) and ADF (ash free)-ADL (ash free), respectively. Starch was hydrolysed according to a two-step enzymatic procedure, using a thermostable amylase followed by amyloglucosidase (Tecator, application note 85/86), and the resulting glucose was measured by the hexokinase glucose-6-phosphate dehydrogenase/NADP system (Boheringer). Procedures of the AOAC International (2000) were also used for dry matter (DM, oven drying method: 934.01), ash (muffle

furnace incineration: 967.05), crude protein (CP, Kjeldahl method: 976.05) and ether extract (EE, with previous hydrolysis in compound feeds and faeces samples).

Growth trial

One hundred and twenty New Zealand White× Californian weaned rabbits 50 days old (30 per diet, 15 males and 15 females per diet) were assigned at random to the different experimental diets. Rabbits were caged individually and offered *ad libitum* access to the feed until they reached slaughter weight. Feed intake, weight gain and mortality were determined from 50 to 88 days of age.

Carcass traits

The one hundred and twenty rabbits were weighed in the experimental building in the afternoon, and then eighty rabbits (20 per treatment, 10 males and 10 females) were randomly selected for analysis of carcass traits. Selected animals were numbered for slaughter order at random and not subjected to fasting. On the next morning, the selected rabbits were transferred in small groups to the slaughter facility near the experimental building in the slaughter order determined above, in this way minimizing stressful conditions. The rabbits were then weighed (SW), electrically stunned, and slaughtered within 2 h. At slaughter, the rabbits were 88 days old.

The slaughtering and carcass dissection procedures followed the World Rabbit Science Association (WRSA) recommendations described by Blasco and Ouhayoun (1996). The slaughtered rabbits were bled, and then the skin, genitals, urinary bladder, gastrointestinal tract and the distal part of legs were removed. Carcasses (with head, thoracic cage organs, liver, kidneys, perirenal and scapular fat) were weighed (hot carcass; HC), then chilled at 4°C for 24 h in a ventilated room. After 24 h chilling, the chilled carcasses (CC) were weighed. The slaughter yield (CC weight as % of SW) and the ratio of the organs and carcass parts to the CC weight were calculated as required. Immediately after weighing, the intermediate (loin joint) and hind parts were individually packed and cooled at 4°C and transported to the laboratory to determine drip loss (calculated as the 48/24 h *post mortem* weight ratio) after thawing. Ultimate

pH was measured after 1 h and 24 h (pH$_1$ and pH$_{24}$) of chilling (Combes et al., 2008) in the muscles *Longissimus lumborum* (LL, adjacent to the sixth lumbar vertebra) and *Biceps femoris* (BF) using a combined glass penetrating electrode (Ingold, Mettler Toledo, Greifensee, Switzerland).

Statistical analysis

Data were analyzed by ANOVA using the GLM procedure of the SAS statistical package (2000) according to the following model:

$$Y_{ijk} = \mu + D_i + S_j + D_i \times S_j + e_{ijk}$$

where:

Y_{ijk} the ijk observation of the dependent variable;

μ general mean;

D_i effect of dietary treatment (i = 1-4);

S_j effect of sex (j = male, female);

$D_i \times S_j$ interaction diet-sex;

e_{ijk} random effect.

The difference among means was tested by Duncan's test.

RESULTS

Bran characteristics and feed particle size

The four diets were formulated to have similar protein and energy contents. The inclusion of hard wheat flour (225 g/kg) in diets containing hard wheat bran was necessary in order to balance diets in terms of starch, as hard wheat bran has a chemical composition similar to soft wheat bran with only the value of starch slightly lower (203.6 vs. 226.4 g/kg). There were no significant differences in the chemical composition of the different types of wheat bran analyzed. The mean particle size composition of the coarse and fine

wheat bran is presented in Table 2. Fine brans were characterized by a higher content of particles of less than 2-4 mm, while only coarse bran contained particles greater than 6-8 mm.

Nutrient utilization

Table 3 shows the feed intake and apparent digestibility of nutrients. The fine hard wheat bran diet had significantly higher DM, OM, CF and fibre fraction (NDF and ADF) digestibility coefficients compared to fine soft wheat bran (p<0.05). Coarse hard wheat bran had intermediate values. There were no significant differences in the digestibility coefficients of CP, EE and ash among the diets or between the mean values for rabbit sex.

Brans from hard wheat positively affected the nutrient digestibilities that was significant for the fine bran (HWB2 diet) when compared with brans from soft wheat, whatever the size. Each digestibility coefficient was lowest with coarse wheat bran from soft wheat (SWB8 diet) which improved, but not significantly, when used with smaller particle size (SWB2 diet). Although fine brans were beneficial (2 vs. 8 mm), the effect of wheat type was larger than that of bran particle size.

Growth trial

The effect of dietary treatments on growth performance is shown in Table 4. No rabbits died during the trial. The final weight of rabbits was significantly affected by the treatments. Body weight at 87 days of age was significantly (p<0.05) lower for rabbits fed diets containing soft wheat bran, regardless of particle size, compared with rabbits on the HWB2 diet. The weight gain of rabbits increased with decreased wheat bran particle size; in particular, rabbits fed the fine hard wheat bran diet showed higher gain (p<0.01) compared to the fine soft wheat bran diet.

Table 3. Effect of the experimental diets and sex on apparent digestibility coefficients (%) obtained using AIA (acid insoluble ash) as the internal marker

	Diet				Sex		SEM[1]	Significance[2]		
	HWB2	HWB8	SWB2	SWB8	Males	Females		D	S	D×S
	No. of rabbits									
	15	15	15	15	30	30				
Feed intake (g/d)	216	216	217	217	215	217	0.95	NS	NS	NS
Apparent digestibility coefficients										
Dry matter	62.7	60.9	57.4	56.7	60.3	57.5	0.59	*	*	*
Organic matter	74.5	70.1	65.2	61.7	70.4	68.9	1.37	*	NS	NS
Crude protein	72.3	71.1	71.4	70.3	71.6	70.8	0.44	NS	NS	NS
Ether extract	70.7	69.9	68.5	67.6	69.2	69.2	0.85	NS	NS	NS
Crude fibre	37.5	35.8	31.6	30.9	35.1	32.5	0.64	*	NS	*
Neutral detergent fibre	56.7	55.2	48.3	45.1	52.6	50.1	1.02	*	*	**
Acid detergent fibre	38.8	32.7	29.1	27.6	33.5	30.7	1.01	**	*	*
Ash	60.2	58.1	58.3	52.1	59.8	54.6	1.87	NS	NS	NS

[1] Standard error of the Least Squares Means. [2] Level of significance: * p<0.05, ** p<0.01. NS = Not significant.

Table 4. Effect of the experimental diets and sex on growth performance of fattening rabbits

Age (d)	Diet				Sex		SEM[1]	Significance[2]		
	HWB2	HWB8	SWB2	SWB8	Males	Females		D	S	DxS
	No. of rabbits									
	30	30	30	30	60	60				
Body weight (g)										
50	1,299	1,302	1,303	1,301	1,300	1,303	3.61	NS	NS	NS
60	1,777	1,712	1,732	1,667	1,721	1,723	7.52	**	NS	*
67	1,987	2,054	2,047	2,114	2,047	2,054	5.87	NS	NS	NS
74	2,294	2,337	2,330	2,373	2,339	2,327	11.1	NS	NS	NS
81	2,663	2,660	2,647	2,643	2,668	2,637	17.2	NS	NS	NS
88	3,061	3,001	2,965	2,905	3,028	2,937	22.6	*	**	*
Weight gain (g/d)										
50-60	47.7	41.2	36.7	43.2	44.1	42.3	0.78	*	NS	*
60-67	45.6	48.8	48.2	45.0	46.5	47.3	0.71	NS	NS	NS
67-74	43.9	40.4	36.9	40.3	41.8	39.0	1.43	**	**	*
74-81	52.8	46.1	38.6	45.2	47.0	44.4	2.21	**	**	**
81-88	56.9	48.8	37.4	45.5	51.5	42.9	2.83	**	NS	**
50-88	47.2	45.1	41.8	43.9	45.8	43.2	0.98	**	**	*
Feed intake (g/d)										
50-60	189	188	191	186	194	192	0.71	NS	NS	NS
60-67	193	192	197	197	195	195	0.69	NS	NS	NS
67-74	196	198	203	202	199	201	0.97	NS	NS	NS
74-81	201	202	202	201	204	199	1.78	NS	NS	NS
81-88	216	216	217	217	203	217	0.95	NS	NS	NS
50-88	202	202	206	204	199	203	1.01	NS	NS	NS
Feed conversion ratio (g/g)										
50-60	3.96	4.58	5.19	4.31	4.41	4.55	0.12	**	**	**
60-67	4.24	3.95	4.09	4.40	4.20	4.13	0.11	NS	NS	NS
67-74	4.49	4.91	5.51	5.02	4.77	5.16	0.19	**	**	**
74-81	3.83	4.40	5.25	4.46	4.35	4.51	0.52	**	*	*
81-88	3.80	4.43	5.83	4.79	3.94	5.08	0.48	**	**	**
50-88	4.29	4.50	4.91	4.67	4.33	4.72	0.22	**	**	**

[1] Standard error of the Least Squares Means. [2] Level of significance: * p<0.05, ** p<0.01. NS = Not significant.

Daily feed intake did not vary significantly as the type of wheat bran and particle size varied. Furthermore, feed intake of rabbits for all treatments was similar during the whole period of the study.

The feed conversion ratio (FCR) increased with an increase in particle size for both types of wheat bran. The FCR was significantly lower (p<0.01) for rabbits fed fine hard wheat bran compared with the other groups. The pattern of the FCR was similar to that of weight gain. Rabbits fed coarse wheat bran had the worst FCR, whereas those fed fine wheat bran had the best trend.

Slaughter trial

Assessment of the carcass traits of fattening rabbits (Table 5) indicated similar carcass weight and dressing percentage for all treatments. Rabbits fed diets containing fine hard wheat bran presented a significantly lower

(p<0.05) proportion of skin and abdominal fat (on % of chilled carcass) compared to animals fed other diets. Similarly, hard wheat bran diets had a positive effect (p<0.05) on drip loss of rabbit carcass resulting in lower loss than carcasses of other treatments. In the model for the statistical analysis of slaughter traits, the sex of rabbits was introduced as a control factor (Table 5). It should be pointed out that the edible part (heart, liver, lungs) of the female was higher than that of the male: 7.52 vs. 7.03% for chilled carcass (p = 0.042). Dietary treatments did not affect pH of LL and BF muscles after 1 h or 24 h post-slaughtering.

DISCUSSION

The effects of dietary treatment were important sources of variation in growth performance and carcass traits of rabbits. An increase in diet digestibility was associated with

Table 5. Effect of the experimental diets and sex on carcass traits of fattening rabbits at 88 days of age

	Diet				Sex		SEM[1]	Significance[2]		
	HWB2	HWB8	SWB2	SWB8	Males	Females		D	S	D×S
No. of rabbits	20	20	20	20	30	30				
Traits (g)										
Slaughter weight (SW)	2,817	2,804	2,773	2,786	2,792	2,798	79.7	NS	NS	NS
Hot carcass	1,774	1,741	1,700	1,733	1,731	1,743	46.8	NS	NS	NS
Chilled carcass (CC)	1,703	1,699	1,679	1,683	1,684	1,698	45.5	NS	NS	NS
% SW										
Slaughter yield	63.0	62.2	61.4	62.3	62.1	62.4	0.22	NS	NS	NS
% CC										
Heart+liver+lungs	7.03	7.45	7.14	7.51	7.03	7.52	0.39	NS	*	*
Skin	13.6	15.9	14.8	16.2	14.1	15.7	0.24	*	*	*
Kidneys	1.23	1.26	1.23	1.27	1.22	1.24	0.11	NS	NS	NS
Digestive tract	14.2	15.1	14.8	15.5	14.9	15.6	0.22	NS	NS	NS
Abdominal fat	1.25	1.51	1.93	2.03	1.30	1.82	0.09	*	*	*
Drip loss (%)	1.01	1.22	2.33	2.90	2.68	2.55	0.12	*	NS	*
pH_1 LL	6.58	6.57	6.74	6.21	6.44	6.43	0.03	NS	NS	NS
pH_{24} LL	6.50	6.45	6.75	6.31	6.49	6.54	0.06	NS	NS	NS
pH_1 BF	5.52	5.58	5.66	5.40	5.54	5.53	0.02	NS	NS	NS
pH_{24} BF	5.60	5.64	5.75	5.62	5.49	5.41	0.04	NS	NS	NS

[1] Standard error of the Least Squares Means; [2] Level of significance: * p<0.05, ** p<0.01. NS: not significant.

the inclusion of hard wheat bran with fine particle size. In addition, by decreasing particle size of diets rabbits obtained the best final weight, gain and feed conversion ratio. The negative association between wheat bran typology (hard vs. soft) and particle size of the diet has been reported previously (Blas et al., 2000). Moreover, the dietary inclusion of soft wheat bran and coarse particle size in this experiment assured a short caecal fermentation time and obviously a high degree of lignification of NDF, which would account for the relatively low efficiency of NDF digestion of these diets. This is in agreement with previous studies (Nicodemus et al., 2007) with growing rabbits and lactating does, which have shown that the extent of NDF degradation of soybean hull was very high after 72 h of fermentation, but also that the degradation rate of its potentially degradable NDF fraction was relatively low. In contrast, when dietary ADL content decreased in rabbit diets because of an increase of fibrous ingredients, a linear increase of accumulation of digesta in the caecum and mean retention time of digesta through the gut was observed (Gidenne et al., 2004).

The ability of rabbits to utilize high-fiber diets results from their ability to regulate the intake of soft faeces during cecotrophy (Iyeghe-Erakpotobor, 2006). Chao and Li (2008) and Chang et al. (2007) reported that cecotrophy in rabbits was more important in the digestion of the protein fraction of forage than in fibre utilization. The digestive physiology of the rabbit is well adapted to high intake of plant cell walls. However, sufficient dietary fibre is essential to prevent digestive troubles but not to improve the growth rate in growing rabbits.

The daily weight gain of rabbits was constant during the study period. Conversely, Iyeghe-Erakpotobor (2006) reported that weight gain followed a pattern of increase and decrease, with a tendency for compensatory growth in weeks following low weight gain or loss in weight. This result was in contrast with Falcao-e-Cunha et al. (2004) who reported a worsening of weight gain in rabbits fed a diet containing wheat bran.

Similar FCR were reported by Lakabi-Ioualitene et al. (2008) in earlier studies with different hard wheat by-product combinations. Although the coarse soft wheat bran group had a poor FCR, this did not seem to significantly affect their daily weight gain or final weight compared with the rabbits fed coarse hard wheat bran. This indicates that growing rabbits are able to efficiently utilize a fine particle size from wheat bran for growth.

The dressing out percentages of 61.4-63% obtained in the present study are higher than values obtained by Lakabi-Ioualitene et al. (2008) and Tao and Li (2006) for crossbred rabbits (New Zealand White, California and Chinchilla combinations). Significant increases in the dietary fiber source or particle size of rabbit diets does not always lead to modifications in slaughter yield (Ouhayoun 1998; Nicodemus et al., 2006).

The inclusion of soft wheat bran led to an increase in rabbit skin percentage; this was probably due to more fat

being associated with the skin as reported also by Dalle Zotte (2002). Rabbits fed soft wheat bran diets (SWB3 and SWB8) tended to be fatter (1.93 and 2.03% of abdominal fat in carcass) compared to animals fed diets containing hard wheat bran (1.25 and 1.51%). These values were observed in a study of rabbits slaughtered at 15 weeks (Lakabi-Ioualitene et al., 2008). Furthermore, the greater fat levels for females observed in this study are generally accepted, as found by Dalle Zotte (2002).

There was a direct relationship between the dietary treatments and drip loss. In fact, drip loss 24 h post-mortem increased when rabbits were fed a diet including soft wheat bran; however, the values obtained were not significantly different between male and female. It is generally accepted that the source of drip from meat is intracellular water that is lost from the muscle fibre *post-mortem*, driven by pH and calcium-induced shrinkage of myofibrils during rigor development (Honikel et al., 1986). The rate and quantity of drip formation in fresh meat is believed to be influenced by the extent of rigor-shrinkage and the permeability of the cell membrane to water as well as other factors such as the extent of protein denaturation.

Omojola (2007) outlined a range of pH values (5.9-6.3) at 3 h *post-mortem* as a good indicator for optimal tenderness and stated that muscles in this pH range were superior in average tenderness and in tenderness uniformity. The result obtained in the present study fell within the range obtained by Smulders et al. (1990). The non-significant shear force values obtained 24-h *post-mortem* might be due to the influence of the pH that fell within the range ideal for superior tenderness score in all treatments. The range value obtained in this study was in agreement with the value obtained by Dalle Zotte et al. (2009) when rabbits were conventionally dressed.

CONCLUSIONS

The present results suggest that the inclusion of fine hard wheat bran may constitute an alternative source of fiber in the diet of fattening rabbits. It is therefore possible to reduce the use of expensive feedstuffs for rabbits by replacing part of the diet with hard wheat by-product. This will reduce the overall cost of feeding and be more profitable, because this result is even more enhanced by a lower cost of hard wheat bran than from the milling of soft wheat. It is concluded that fine hard wheat bran can be fed to rabbits without adverse effects on growth performance and carcass traits compared to the inclusion of fine or coarse soft wheat bran, commonly used in rations for fattening rabbits. Further studies are necessary to evaluate the effects of other levels of inclusion of fine hard wheat bran on performance of rabbits.

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