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EFFECT OF GRINDING AND EXTRUSION ON THE DIGESTIBILITY OF WHEAT AND CORN BY RABBITS

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ABSTRACT

The effect of grinding size and extrusion on the digestibility of wheat and corn was determined using fifty four New Zealand x Californian rabbits of about 65 days of age. Both cereals were ground using a screen of 4 mm (coarse) and 2 mm (fine). Finely ground grains were extruded after adding 10% of water, at 180ºC and 75 atm. of pressure. These grains were included at 30% on a basal diet to determine their nutritional value. An analysis of variance over the digestibility coefficients was performed, being separated the effects of cereal type, degree of grinding, extrusion and their interactions by orthogonal contrasts. Dry matter, OM, and CP digestibility of diets was affected by the cereal type ($P<0.05$), being wheat based diets 2-6 % more digestible than corn based diets. There was no effect of grinding size on nutrient digestibility. An effect of extrusion was shown for NDF and CP digestibility, although in an inverse way; NDFd increased 11% ($P=0.055$) and CPd decreased 5% ($P=0.023$) with the extrusion process. An interaction of cereal type by extrusion was also shown for all nutrients except NDF indicating a positive effect of extrusion on DM, OM and energy digestibility of corn and a negative effect on wheat. As a consequence, wheat had higher nutritional value (3.60 Mcal DE/kg DM, 86.4%CPd) than corn (3.48 Mcal DE/kg DM, 57.2%CPd), this difference being more important when unextruded grains were compared. Extrusion increased the energy value of corn (up to 3.68 Mcal DE/kg DM) and decreased that of wheat (up to 3.44 Mcal DE/kg DM)

INTRODUCTION

Cereal grains are usually included in rabbit diets at 15-25% (DE BLAS and MATEOS, 1998). Barley is the most commonly used followed by wheat and corn. Although they are the main energy sources in rabbit diets, their nutritional value are not accurately established. Thus, some studies seem to indicate that the energy value of corn is lower than that of wheat (MAERTENS and DE GROOTE, 1984) or even barley (VILLAMIDE and DE BLAS,1991) probably due to its lower starch digestibility (BLAS et al., 1990), while others (FERNÁNDEZ-CARMONA et al. 1996) obtained a higher energy value for corn than for barley. On the other hand, new technologies both in the field of grinding (i.e. roller mills) or in mash conditioning (i.e. expansion, extrusion) are emerging in feed manufacturing, and could be used in rabbit diets. The effect of these new technologies has been scarcely studied (MAERTENS and LUZI,1995) in rabbits. Therefore, the aim of this study was to evaluate the effect of grinding and extrusion on the nutritional value of corn and wheat.

MATERIAL AND METHODS

Feedstuffs and processing of grains. A sample of commercial corn and wheat (Triticum durum), which composition is shown in Table 1, was used in this study. Both ingredients were ground using a screen of 4 mm (coarse ground) and 2 mm (fine ground). The distribution of particle size is shown in Table 2. Finely ground grains were moistened (10% added water) and extruded at 180º C with 75 atm. of pressure, 100 rpm. being the double-screw speed. These grains were used as main ingredients in the experimental diets. Both processing of

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grains and diets manufacturing were done in the Dpto. de Ciencia Animal of the Universidad Politécnica de Valencia

Table 1. Chemical composition of corn and wheat (%DM) used in this study.

Cereal grain	Corn			Wheat		
Grain processing	Grind			Grind		
	Coarse	Fine	Extrusion	Coarse	Fine	Extrusion
Dry Matter	87.73	88.22	94.77	89.88	89.54	93.05
Ash	1.42	1.50	1.54	1.78	1.80	1.90
Crude Protein	9.20	8.97	9.12	11.53	11.63	11.82
Neutral Detergent Fibre	13.49	13.79	11.57	15.48	15.69	13.42
Acid Detergent Fibre	3.04	2.87	4.57	4.50	4.03	6.66
Acid Detergent Lignin	0.59	0.64	1.68	1.26	1.28	2.02
Gross Energy (Mcal/kgDM)	4.53	4.54	4.54	4.45	4.41	4.43

Table 2. Distribution of particle size (%) in function of cereal type and degree of grinding.

Particles higher than:	Corn		Wheat	
	Coarse	Fine	Coarse	Fine
2.5 mm	0.3	0.1	0.2	0.1
1.25 mm	28.5	14.2	42.0	19.7
0.63 mm	32.8	34.2	30.0	35.8
0.31 mm	20.7	27.0	14.5	22.3
<0.31 mm	17.7	24.5	13.3	22.1

Experimental Diets. A basal diet composed of 9.3% soyabean meal, 5.7% sunflower seed meal, 40.7% alfalfa meal, 28.6%wheat bran, 14.3% barley straw, 0.35% lysine, 0.4% calcium carbonate, 0.35% sodium chloride, and 0.3% vitamin-mineral premix was formulated. This basal diet was substituted by 30% of processed grains (coarse or fine ground, or extruded) to determine by difference their nutritional value. Due to the different moisture content of extruded grains and basal diet, the actual substitution rate of grains in the basal diet were: 29.5; 29.6 and 31.1 % for coarse, finely ground and extruded corn, respectively, and 30, 30 and 30.6 % for coarse, finely ground and extruded wheat, respectively. Chemical composition of experimental diets is shown in Table 3.

Table 3. Chemical composition of experimental diets (% DM)

Diets	Corn			Wheat			Basal
Grain processing	Grind			Grind			
	Coarse	Fine	Extrusion	Coarse	Fine	Extrusion	
Dry Matter	89.99	90.13	91.30	90.96	90.94	91.80	91.20
Ash	6.62	6.75	6.58	6.97	6.79	6.92	9.18
Crude Protein	15.67	16.13	15.75	17.18	16.84	17.17	18.82
Neutral Detergent Fibre	37.05	36.35	35.99	35.57	36.07	36.56	45.06
Acid Detergent Fibre	18.72	18.23	19.38	18.65	18.83	20.99	25.57
Acid Detergent Lignin	4.74	4.58	5.73	4.53	4.17	4.89	5.66
Gross Energy (Mcal/kg DM)	4.38	4.38	4.39	4.36	4.34	4.37	4.42

Digestibility trial. Ten rabbits per diet from a growth assay were taken and adapted to the metabolism cages for 3 days when they were 60-65 days old. Those with basal diet were taken with 49 to 60 d of age and adapted to diets in the metabolism cages for 10 days. The live weight at the beginning of the digestibility period was 1404±50.4 g. The digestibility assay was developed following the European Reference Method, (PEREZ et al. 1995). The number of rabbits at the end of the digestibility period varied from 7 to 9 as some animals were discarded because of digestive problems.

Analyses. Analyses were conducted according to AOAC (1991) for DM, ash, CP, crude fibre (CF) and ether extract. Neutral detergent fibre, ADF and ADL were analysed sequentially (VAN SOEST et al., 1991). Gross energy was determined by adiabatic calorimetry. Particle size of grains was determined by dried sieving of 50 g of ground cereals. The samples were emptied onto a sieve stack with four sieves with decreasing pore sizes (2.5, 1.25, 0.63, 0.31 mm). After one hour of continuous vibration, the content of the different sieves was weighed and expressed as a percentage of the total sample.

Statistical analyses were performed as a completely randommised design using the GLM procedure of SAS (1991). An analysis of variance was carried out over the 6 experimental grain based diets, diet being the main source of variation. Orthogonal contrasts were performed to separate the effect of cereal type, grinding size, extrusion and their interactions on the digestibility coefficients. The nutritional value of corn and wheat and their different processing were estimated by difference between the nutritional value of grain based diets and basal diet. Mean values and standard error of the estimates were calculated following the equations proposed by VILLAMIDE (1996).

RESULTS AND DISCUSSION

The effect of cereal type and method of processing of grains on the digestibility of experimental diets is shown in Table 4. Type of cereal affected significantly dietary digestibility of all nutrients except NDF that was similar for both cereals (24.9 % as average). Dry matter, OM and GE digestibility were about 2% higher (P=0.018 for DMd and OMd, P=0.054 for GEd) for wheat than for corn based-diets. As a consequence, average GEd of wheat were higher than corn (81.2 vs 76.8% GEd, Table 5). Similar results have been obtained by MAERTENS and DE GROOTE (1984) comparing GEd of soft wheat and corn (79.2 vs 77.9%) and by VILLAMIDE and DE BLAS (1991) when comparing corn with barley (76.2 vs 80.2%). This low GE digestibility of corn compared to other cereals could be due to its relatively lower starch digestibility (92 vs 99%, and 97 vs 99% of corn vs barley, from Blas et al. 1990 and GIDENNE and PEREZ, 1993, respectively). The reason for this relatively low starch digestibility of corn could be the hardness of its endosperm, as a consequence of a strong link between protein matrix and starch granules which is not broken in presence of water (HOSENEY, 1991). In fact, the protein was already less digested than other nutrients (P<0.002) in corn (69.4%) compared with wheat (73.5%) based-diets.

There was no effect of cereal grinding (P>0.05) on nutrient digestibility indicating no effect of particle size of cereals on their nutritional value, unlike the particle size of fibre which affects fibre digestion, rate of passage and feed intake in rabbits (GARCÍA et al. 1999). Despite some authors (GIDENNE and PEREZ, 1993, CARABAÑO, 1995) arguments that the coarser grinding of corn is one of the reasons of its relatively low digestive utilisation, this does not seem to be the reason in our study, as particle size was greater for wheat than for corn (Table 2).

Extrusion only affected significantly NDF and CP digestibility but in an inverse way. Thus NDFd increased 11% (P<0.055) on average when extruded grains were compared with finely ground grains. The thermo-mechanical process of extrusion makes partially soluble the hemicellulose fraction and increases the polysaccharide fragmentation (VUKIC VRANJES and WENK, 1995). In fact, the NDF content of extruded grains was 2.2 points lower than those finely ground. Moreover, in an experiment with rats, BJÖRCK et al. (1984) showed that dietary fibre in extruded wheat flour was more extensively degraded than in raw material. On the contrary, both residues of ADF and ADL were greater (2.2 and 0.9 points on average for ADF and ADL, respectively) for extruded grains than for those finely ground. This increase in ADF and ADL in extruded grains could indicate Maillard reactions, which insoluble products are collected both in ADF and ADL residues (VAN SOEST, 1994). These reactions between the most reactive amino acids and reducing sugars (VORAGEN et al.,1995) also explain the lower CPd of extruded grains compared to those finely ground (69.5 vs 73.0 %, P=0.023). This effect was clearer in wheat than in corn (interaction type of cereal by extrusion P=0.097). Interaction type of cereal by extrusion was also significant for DM, OM and GE digestibilities (P<0.05). Extrusion increased GE digestibility of corn by 3.7% but decreased that of wheat based-diets by 2.6%, being the effect on DM and OM digestibility of the same order. This could indicate, besides the Maillard reactions before mentioned, formation of resistant starch which is not digestible by monogastric animals (VORAGEN et al.,1995). This would affect more strongly wheat because both protein and starch are very well digested. In the case of corn the solubilisation of starch and fibre (VUKIC VRANJES and WENK, 1995) seems to account for more energy than the possible retrogaded starch and Maillard products. In fact the ADF insolubilisation was higher for wheat than for corn (2.63 and 1.7 points, respectively).

The same effects mentioned above for experimental diets, are more clearly shown in Table 5, where the nutritional value of corn and wheat is presented. Data have been estimated by difference from the nutritional value of cereal-based diets and basal diet. Thus, the nutritional value of wheat is considerably greater than of corn both in energy (3.60 vs 3.48 Mcal DE/kg DM) and protein (CPd 86.4 vs 57.1%), and mainly when the grains were supplied unextruded (differences of 9% and 70% for DE and CPd, respectively). The fibre of both cereals are relatively well digested (NDFd 50.1% and 63.1% for wheat and corn, respectively) as a consequence of its low lignin and high hemicellulose content. Extrusion increased the DE content of finely ground corn by 8% (3.41 vs 3.68 Mcal/kg DM) as a consequence of a higher NDF digestibility (40.6 vs 77.4 %), and probably a higher starch digestibility. On the contrary, extrusion impaired the nutritional value of wheat, both its DE content (3.64 vs 3.44 Mcal DE/kg DM) and its CP digestibility (97.2 vs 67.6%), the only profit was a higher NDF digestibility.

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Table 4. Effect of cereal type and of processing method on nutrient digestibility of experimental diets[1](%)

Grain	Corn			Wheat				Significance of Orthogonal Contrasts				
Processing	Grind		Extrusion	Grind		Extrusion						
	Coarse	Fine		Coarse	Fine		SEM	Cereal[2]	Grinding size[3]	Extrusion[4]	Cereal x Grinding size	Cereal x Extrusion
n	7	7	8	8	8	7						
DMd	60.15	60.39	62.51	62.97	62.92	61.28	0.68	0.018	0.891	0.724	0.835	0.009
OMd	60.25	60.36	62.80	63.04	63.03	61.48	0.68	0.018	0.942	0.517	0.933	0.006
NDFd	25.92	23.14	26.11	24.94	23.67	25.78	1.28	0.805	0.122	0.055	0.560	0.742
CPd	68.97	70.22	69.24	74.95	75.75	69.70	1.48	0.002	0.494	0.023	0.665	0.097
GEd	58.55	58.90	61.10	61.46	61.16	59.56	0.75	0.054	0.969	0.689	0.883	0.015

[1] Digestibility of basal diet 51.85, 51.03, 21.28, 72.33 and 50.56% for DM, OM, NDF, CP and GE, respectively.
[2] Corn vs wheat; [3] coarse vs fine ground; [4] fine ground vs extrusion,

Table 5. Nutritional value of corn and wheat under different processing methods (mean ± standard error)

	Corn			Wheat		
	Coarsely ground	Finely ground	Extruded	Coarsely ground	Finely ground	Extruded
DE (Mcal/kg MS)	3.36	3.41	3.68	3.72	3.64	3.44
	±0.10	±0.11	±0.17	±0.09	±0.11	±0.13
GEd	74.2	75.2	81.0	83.5	82.7	77.5
	±2.2	±2.3	±3.8	±2.07	±2.4	±2.84
NDFd	71.5	40.6	77.4	46.4	38.6	67.6
	±13.2	±11.2	±18.0	±14.5	±11.1	±9.8
CPd	51.7	61.0	58.7	94.3	97.3	67.6
	±1.2	±6.9	±11.5	±5.3	±5.77	±11.7