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NUTRITIVE VALUE OF DEHYDRATED WHOLE MAIZE PLANT AND ITS EFFECT ON PERFORMANCE AND CARCASS CHARACTERISTICS OF RABBITS

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Abstract: Seven diets were formulated in order to determine the nutritive value of whole maize plant at three stages of maturity by substitution of a control diet (C) with 20% and 40% whole maize plant at early dough, mid-dent and mature stages of grain. A digestibility trial was performed with 74 rabbits. Digestible protein and energy values of whole maize plant at different maturity stages were calculated by substitution and regression procedures. A fattening experiment was carried out with 200 rabbits from weaning (28 days of age) giving *ad libitum* either diet C or 20% mature whole maize plant. One hundred and forty-three rabbits were slaughtered at 63 days of age and some carcass traits were measured.The crude protein and fibre content of whole maize plant decreases as the kernel matures (CP: 8.3, 8.1 and 7.6% DM; CF: 15.8, 12.6 and 13.4% DM; NDF: 45.3, 38.0 and 38.0% DM; ADF: 19.1, 15.0 and 16.1% DM for early dough, mid-dent and mature stages, respectively). The digestible energy concentration, calculated by regression, of whole maize plant increased (P<0.01) with maturity stage (8.5, 9.5 and 10.4 MJ/kg DM, respectively) but the digestible protein value was higher (P<0.01) at the intermediate maturity stage (3.7, 4.5 and 3.2% DM). Rabbits given the diet with 20% plant maize at the maturity stage had similar feed intake (101 *vs.* 99 g DM/d) and live weight gain (44 *vs.* 45 g/d) but a worse feed conversion index than C rabbits (2.29 *vs.* 2.21, P=0.03). No differences were found at slaughter in live weight, carcass characteristics and dressing percentage of rabbits fed the two experimental diets.

Key Words: maize plant, digestibility, nutritive value, growth performance, carcass traits.

INTRODUCTION

Maize is one of the most important cereals in the world both for human consumption and livestock feeding. Maize grain is used for all livestock production while the whole maize plant is traditionally used for ruminants, mostly as silage (Aquino *et al.*, 1999). The whole maize plant is also available in dehydrated and ground form for ruminant nutrition and could be useful for rabbit feeding, but little information is available on its nutritive value.

Maize grain has a digestible energy (DE) content much higher than maize stover and it is assumed that the quality of forage maize is determined only by the ear to stover ratio, but this trait does not adequately predict the nutritional value of maize (Bertoia *et al.,* 2002). Due to its high humidity, whole maize plant requires to be dehydrated before inclusion in pelleted diets for rabbits and the maturity stage is important, since the dry matter (DM) content of maize plant increases from 23 to 37% during the maturing process of the grain (Abreu *et al.*, 2000). In general, immature maize has a higher protein concentration than mature maize (Tolera and Sundstol, 2001; Michalet-Doreau *et al.*, 2004), but a

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lower energy value. As grain progresses from early dough stage to commercial maturity, the percentage of grain in the plant increases, and consequently crude protein (CP) and crude fibre (CF) decrease while starch increases (Mader *et al.*, 1983).

On dehydrated whole maize plant at mid-dent stage, Costantini *et al.* (1978) obtained an organic matter digestibility of 60%, a protein digestibility of 87% and a net energy value of 6.7 MJ/kg. Lui *et al.* (2004) recorded lower CF and CP digestibility coefficients for whole maize plant than for alfalfa hay. The inclusion of from 20 to 40% of dehydrated whole maize plant at the mid-dent stage in rabbit diets did not affect daily growth or carcass yield, but increased daily feed intake, while the feed conversion ratio was impaired and perirenal fat was lowered in rabbits given 40% of whole maize plant (Masoero *et al.*, 1979; Auxilia *et al.*, 1979).

The aims of this experiment were to determine the nutritive value of whole maize plant at different stages of maturity for rabbits and to examine the effect of its inclusion in the diet of fattening rabbits on performance and carcass characteristics.

MATERIAL AND METHODS

The mature maize plants were collected, dehydrated and ground in November by the industrial processes followed for ruminant feeding purposes. Some quantities of the same maize plants had previously been collected manually in August, at the early-dough stage of the grain, and in September, at the mid-dent stage. The industrial processes were reproduced on these plants in the experimental feed factory of the Polytechnic University of Valencia: fresh plants were cut manually, dehydrated in an oven at 80º C (Selecta P. Invester S.3744) to obtain a DM content of 85% and ground with a mill (Skiold HST Wind). The chemical composition of dehydrated whole maize plant at different maturity stages is shown in Table 1.

Seven pelleted diets were formulated, in order to determine the nutritive value of whole maize plant at the three stages of maturity. The ingredients and chemical composition of diets are shown in Table 2. The control diet (C) was a standard rabbit diet including alfalfa, barley and soya bean as main ingredients. The experimental diets were made by substitution of 20 and 40% (on DM basis) of dehydrated whole maize plant at early dough (E20 and E40 diets), mid-dent (M20 and M40 diets) and full maturity stages (F20 and F40 diets).

Table 1: Chemical composition (% DM) of dehydrated whole maize plant collected at early dough (E), mid-dent (M) and full (F) maturity stage.

	E	M	F
Dry matter (DM; %)	89.1	89.2	89.3
Ash	4.2	3.2	4.6
Crude protein	8.3	8.1	7.6
Ether extract	3.2	2.4	2.5
Crude fibre	15.8	12.6	13.4
Neutral detergent fibre	45.3	38.0	38.0
Acid detergent fibre	19.1	15.0	16.1
Acid detergent lignin	1.1	1.0	1.3
Gross energy (MJ/kg DM)	18.7	18.3	18.2

Table 2: Ingredients (% DM) and chemical composition (% DM) of the experimental diets.[1]

	C	E20	E40	M20	M40	F20	F40
Ingredients							
Alfalfa hay	48.0	38.1	28.2	38.1	28.2	38.1	28.2
Whole maize plant	0.0	20.0	40.0	20.0	40.0	20.0	40.0
Barley grain	35.0	27.8	20.6	27.8	20.6	27.8	20.6
Soya bean meal	12.0	9.5	7.0	9.5	7.0	9.5	7.0
Animal fat	2.0	1.6	1.2	1.6	1.2	1.6	1.2
DL methionine	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dicalcium phosphate	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Sodium chloride	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Mineral/vitamin premix[2]	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Chemical composition							
Dry matter (%)	91.3	90.0	91.6	90.4	91.5	90.8	91.6
Ash	9.1	7.8	7.1	8.1	7.0	7.8	6.7
Crude protein	18.5	15.8	13.3	16.0	13.5	16.0	12.8
Ether extract	4.8	4.1	3.6	4.2	4.0	3.5	3.3
Crude fibre	15.5	16.9	18.6	16.3	16.2	14.1	17.3
Neutral detergent fibre	30.3	34.6	38.6	32.2	34.9	30.9	37.9
Acid detergent fibre	17.6	19.4	20.5	18.1	18.8	16.7	20.2
Acid detergent lignin	2.5	2.3	2.1	2.6	2.0	2.4	2.0
Gross energy (MJ/kg DM)	18.1	18.2	17.6	18.7	17.6	17.9	17.8

[1]Diets: C, control; E20 and E40, dehydrated whole maize plant at early dough stage included at 20 or 40%; M20 and M40, whole maize plant at mid-dent stage included at 20 or 40%; F20 and F40, whole maize plant at full maturity stage included at 20 or 40%. All diets contained 100 ppm $CuSO_4\ 5H_2O$, 50 ppm BHT antioxidant, 50 ppm α-tocopherol and 66 ppm robenidine (©Ciclostat: 800 ppm, except in the week before slaughtering).
[2]Contains (g/kg): thiamin, 0.25; riboflavin, 1.5; calcium pantothenate, 5; pyridoxine, 0.1; nicotinic acid, 12.5; retinol, 2; cholecalciferol, 0.1; α-tocopherol, 15; phytylmenaquinone, 0.5; cyanocobalamin 0.006; choline chloride, 100; $MgSO_4\ H_2O$, 7.5; ZnO, 30; $FeSO_4\ 7H_2O$, 20; $CuSO_4\ 5H_2O$, 3; KI, 0.5; $CoCl_2\ 6H_2O$, 0.2; Na_2SeO_3, 0.03.

A digestibility trial was performed, following Perez *et al*. (1995), on 74 rabbits of 42 days of age (8-13 rabbit per diet) to obtain the digestibility coefficients of DM, CP and gross energy (GE). Diets were offered *ad libitum* and after an adaptation period of 1 week, samples were collected during a 4-day period. Diets and faeces were analysed according to the European Group on Rabbit Nutrition recommendations (EGRAN, 2001).

A 5-week fattening experiment was carried out with 200 rabbits (males and females of a three-way crossbreed). At weaning (28 days of age), they were randomly distributed into two groups and fed the diets C and F20. This diet, containing 20% of whole maize plant at the full maturity stage, was selected because of the results obtained in the digestibility trial and the available commercial supply of whole mature maize plant. The rabbits were placed in individual cages (45 × 30 cm) and had free access to water and feed. The daily minimum and maximum indoor temperatures averaged 14 and 20°C, respectively, and a lighting schedule of 12 h of light was used. Feed intake, live weight gain and daily mortality were recorded from weaning to slaughter, following the recomendations for applied nutrition experiments in rabbits of the EGRAN (Fernández-Carmona *et al.,* 2005).

Without fasting, 143 rabbits (73 and 70 rabbits for C and F20 diets, respectively) were slaughtered at 63 days of age and carcasses stored at 3°C for 24 h. The following variables were measured: live weight, skin weight, full gastrointestinal tract weight, chilled carcass weight and liver weight. Dissectible fat weight was the sum of the scapular and perirenal fat depots.

The digestibility coefficients of experimental diets were analysed, using the General Linear Model procedure of the Statistical Analyse System Institute (SAS, 1990) with incorporation level, maturity stages of whole maize plant and their interaction as main effects. Contrasts were computed to test the significance of the differences observed between diets.

The DE and digestible protein (DP) values of whole maize plant at each state of maturity were calculated both (a) by the difference between the nutritive value of diets for each substitution rate (20 and 40%) and (b) by extrapolation to a total substitution of the regression between the digestible nutrient content of experimental diets and the substitution rates. Mean value and standard errors were calculated following the methodology of Villamide *et al.* (2001). The SAS regression procedure was used and the confidence interval of the values estimated by the different methods was calculated using a *t*-test.

Results from the fattening and carcass experiments were subjected to analysis of variance using the General Linear Model program of the SAS. Sex was found not to be significant for any of the variables studied, so the definitive model included diet as the only factor, using the live weight as covariate for carcass measures. A chi-square test was used to analyse the frequencies associated with mortality.

RESULTS AND DISCUSSION

The chemical composition of whole maize plant utilized in this research is similar to that reported by Mader *et al*. (1983), Tolera and Sundstol (2001) and Michalet-Doreau *et al*. (2004). The whole maize plant is a forage with a moderate content of fibres and low content of CP (from 4 to 13% DM) and acid detergent lignin (from 1.0 and 7.4% DM) (Dardenne *et al*., 2005). During the maturing process of the plant, the cell wall content of stover increases (Flachowsky *et al.,* 1993), but as the grain progresses, from the early dough stage to full maturity, the percentage of grain in the ear increases as does the ear-to-stover ratio. Consequently, the CP and fibre-content of the whole maize plant decrease and the DE increases, presumably due to the starch increase.

The results from the digestibility trial are shown in Table 3. No interactions between the incorporation level and maturity stage were found. The incorporation level and maturity stages of whole maize plant affected the digestibility coefficient of DM and GE. Feed intake was affected by maturity stage.

The inclusion of whole maize plant in the diet did not affect CP digestibility since the protein source was of the same for all diets (alfalfa and soya bean, as main sources), but the digestibility coefficient of DM and GE were lower in whole maize plant diets than in the control diet (65, 62 and 61% for DM, P=0.02; and 64, 62 and 60% for GE, P<0.01, respectively for control, 20% and 40% whole maize plant), probably due to the increase of fibre contents in diets. Similar results were found by Masoero *et al.* (1979) when whole maize plant at early dough stage replaced maize grain. Lui *et al.* (2004), replacing alfalfa hay with whole maize plant at the fully mature grain stage, found lower values for digestibility coefficients of DM (55%) and GE (60%), but no differences between diets were found, whereas the digestibility coefficient of CP decreased with the dietary inclusion of maize plant (62%).

Table 3: Effect of maturity stage (S) and inclusion level in diet (L) of whole maize plant on feed intake and digestibility of experimental diets*.

	C	E20	E40	M20	M40	F20	F40	RSD	*P*-value S	*P*-value L
Rabbits (No.)	12	10	13	9	8	9	13			
Feed intake (g/d)	122[ab]	136[a]	128[ab]	114[b]	121[ab]	124[ab]	112[b]	16	<0.01	0.29
Digestibility coefficients (%):										
Dry matter	65[a]	59[c]	59[c]	62[b]	61[bc]	64[a]	62[b]	2	<0.001	0.02
Crude protein	72	68	70	72	71	71	70	3	0.08	0.84
Gross energy	64[a]	59[d]	58[d]	63[ab]	60[cd]	64[a]	62[bc]	2	<0.001	<0.01

*Diets: C, control; E20 and E40, whole maize plant at early dough stage included at 20 or 40%; M20 and M40, whole maize plant at mid-dent stage included at 20 or 40%; F20 and F40, whole maize plant at full maturity stage included at 20 or 40%.
a,b,c: values with different superscript in a same row differ with $P<0.05$.

Feed intake was higher with early dough whole maize plant diets ($P<0.01$) and coefficients of digestibility of DM ($P<0.001$), CP ($P=0.08$) and GE ($P<0.001$) increased during the grain maturing process (59, 61 and 63% for DM and GE; 69, 71 and 71% for CP, respectively for early dough, mid-dent and mature maize plant), presumably due to the higher starch concentration in the diets with the more mature maize (Blas *et al.*, 2000) and the lower feed intake. Consequently, the DE value of whole maize plant calculated from the digestibility of the diets increased with the maturity stage ($P=0.03$) independently of the method of estimation: substitution or regression (Table 4). The DP values were low in all stages because of the low CP concentration of whole maize plant and its moderate digestibility (42%). Moreover, the two methods of estimation used gave different DP values for whole plant maize at the mature stage. A significantly higher DP content ($P<0.01$) was found in the mid-dent stage using a regression methodology, due to a reduction in the standard error of estimates, but no difference was found by substitution methods.

The estimates of DP and DE obtained by regression and substitution at the 40% level were very close to each other, but the substitution at the 20% level showed a higher difference in absolute values and high standard errors. This effect has been discussed by Villamide *et al.* (2003), who pointed out the regression procedure as the more reliable method to estimate the nutritive value of raw material.

Table 4: Estimation of nutritive value of whole maize plant collected at early dough (E), mid-dent (M) and full (F) maturity stages for rabbits (means ± standard error).

		E	M	F	*P*-value
Digestible energy (MJ/kg DM) [1]	Substitution 20%	7.9[a] ± 0.7	12.3[b] ± 1.0	12.2[b] ± 1.0	0.03
	Substitution 40%	8.6[a] ± 0.4	9.3[ab] ± 0.3	10.4[b] ± 0.3	0.03
	Regression	8.5[a] ± 0.1	9.5[b] ± 0.3	10.4[b] ± 0.1	<0.01
Digestible protein (% DM) [1]	Substitution 20%	3.5 ± 1.2	4.7 ±0.9	5.4 ± 1.2	0.37
	Substitution 40%	3.7 ± 0.5	4.5 ± 0.3	3.0 ± 0.4	0.43
	Regression	3.7[a] ± 0.2	4.5[b] ± 0.1	3.2[a] ± 0.2	<0.01

Values determined by substitution (20 and 40% levels) and regression procedures from digestibility of the experimental diets according to Villamide *et al.* (2001). a, b: values with different superscript in a same row differ with $P<0.05$
[1] Number of rabbits: Substitution 20%: 10, 9 and 9 for E, M and F groups, respectively. Substitution 40%: 13, 8 and 13 for E, M and F groups, respectively, Regression: 35, 29 and 34 for E, M and F groups, respectively.

Table 5: Performance of growing rabbits given two experimental diets.

	C	F20	RSD	*P*-value
Rabbits (No.)	73	70		
Live weight gain (g/d)	45	44	5.6	0.50
Feed intake (g/d)	99	101	13.3	0.34
Feed conversion ratio (g DM/g)	2.21	2.29	0.21	0.03
Mortality (%)	25	29		0.81

Diets: C, control; F20, mature whole maize plant included at 20%

The nutritive characteristics were similar to those of citrus or sugar beet pulps. For the lower fibre fraction concentration, the DE value is higher than the principal forages used in rabbit nutrition (hulls, cereal straw, grape by-products or alfalfa) and only alfalfa and bran have higher DP concentrations (De Blas *et al.*, 2003).

The overall results of rabbit performance are shown in Table 5. No significant differences were found in feed intake and live weight gain between diets, but rabbits given the F20 diet have a higher feed intake and lower live weight gain than the C diet and, consequently, the feed conversion index was higher in F20 rabbits (P=0.03). A high rate of mortality was recorded due to epizootic enteropathy, but was similar in the two groups. Similar results were found by Masoero *et al.* (1979), who recorded differences in the daily intake and feed conversion index with increased whole maize plant in the diet and no effect on daily growth rate. Auxilia *et al.* (1979) recorded an impaired feed conversion ratio in rabbits given 40% of whole maize plant, but not with a 20% diet.

Carcass traits are shown in Table 6. No differences were found in live weight, chilled carcass weight, liver weight, dissectible fat, skin weight and full digestive tract and, consequently, the dressing percentage of rabbits was similar in both groups. Auxilia *et al.* (1979) recorded the same carcass yield in rabbits given diets with 20 and 40% of whole maize plant in comparison with a control diet and lower perirenal fat in rabbits fed 40% maize, but not with 20% maize.

Results from this experiment show that the maturity stage of whole maize plant affects the fibre and protein concentration as well as the DE and DP values. Whole maize plant of fully mature grain can

Table 6: Slaughter traits of rabbits given two experimental diets.

	C	F20	RSD	Prob.
Rabbits, No.	73	70		
Live weight (g)	2135	2117	197	0.58
Skin weight (g)[1]	292	287	19	0.10
Full gut weight (g)[1]	438	438	46	0.92
Chilled carcass weight (g)[1]	1195	1196	44	0.87
Liver weight (g)[1]	100	102	17	0.49
Dissectible fat (g)[1]	15.6	16.6	3.5	0.11
Dressing yield (%) [1]	56.1	56.2	2.2	0.83

Diets: C, control; F20, mature whole maize plant included at 20%. [1]Significant effect (P<0.001) of the covariate (live weight).

be defined as a fibrous feed with a moderate fibre concentration but low in lignin, low in CP with moderate digestibility and high DE concentration. Dehydrated whole maize plant can be utilised in rabbit diets at least at the 20% inclusion rate without affecting feed intake, growth rate, dressing yield and carcass characteristics, although it could impair feed efficiency.

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