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Dark and Yellow Rapeseed Hulls, Soybean Hulls and a Purified Fiber Source: Their Effects on Dry Matter, Energy, Protein and Amino Acid Digestibilities in Cannulated Pigs

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DARK AND YELLOW RAPESEED HULLS, SOYBEAN HULLS AND A PURIFIED FIBER SOURCE: THEIR EFFECTS ON DRY MATTER, ENERGY, PROTEIN AND AMINO ACID DIGESTIBILITIES IN CANNULATED PIGS[1]

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Summary

Hulls from Tower rapeseed (dark colored cultivar), R500 rapeseed (yellow colored cultivar) and soybean were included in semi-purified diets for growing pigs at 10%, to investigate the effects of these fiber sources on dry matter, energy and protein digestibilities. Celufil, a purified fiber source, was also included in another diet at a 10% level for comparison. Casein, which was the main protein source, was added at a 15% level in all the diets. Four 40-kg barrows fitted with cannulas at the terminal ileum were used in a digestibility trial with a 4 × 4 Latin square design. The digestibilities of dry matter, protein and amino acids were measured to the ends of both the small and large intestines, while the digestibility of energy was measured only over the entire gastro-intestinal tract. The true protein digestibility was also determined at the ileal and fecal levels. The Celufil diet had a higher cellulose content (8.7%) than the other diets (2.8 to 5%). The Tower rapeseed hull diet contained the highest lignin percentage (2.9), while the Celufil diet had the lowest value (.06). The dry matter and energy digestibility values were lowest with the Celufil diet. Highly significant negative correlations between the digestible energy and the dietary crude fiber, neutral detergent fiber, acid detergent fiber and cellulose were respectively shown. Protein and majority of amino acid digestibility values were higher ($P<.05$) with the Celufil diet than with the hull diets. The dark rapeseed hull diet had the lowest protein digestibility value at the terminal ileum. However, there were no differences ($P>.05$) in protein digestibility values for the hull diets measured over the total digestive tract. The digestibility values of dry matter, protein and amino acids were lower at the terminal ileum than at the fecal level. The results suggest that cellulose can be included in swine diets up to 9% without a deleterious effect on protein and amino acid digestibilities, although this level will lower dry matter and energy digestibility values. The lignin content of the diets and possibly other undetermined factors appear to have some adverse effects on protein and amino acid digestibilities.

(Key Words: Rapeseed Hull, Dietary Fiber, Energy, Protein, Amino Acids, Cannulated Pigs.)

Introduction

The rapeseed hull is usually dark in color and constitutes 16.5 to 18.7% of the seed on the dry matter basis (Appelqvist and Ohlson, 1972). Plant breeders have, however, developed seeds with yellow hulls. The yellow hulls

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contain about 40% of the crude fiber found in the dark hulls (Stringham et al., 1974). They also contain less lignin than the dark hulls (Bell and Shires, 1982; Mitaru et al., 1982). The crude fiber content and some other factors in the hull contribute to the lower nutritional value of rapeseed meal as compared with soybean meal (Lodhi et al., 1970).

This study was conducted to compare the effects of dark and yellow rapeseed hulls on the digestibility of the dietary dry matter, energy, protein and amino acids in growing pigs. Soybean hulls and a purified fiber source (Celufil) were included for a further comparison.

Materials and Methods

Fiber Sources. The rapeseed hull fractions were obtained by passing clean seeds through a disk mill equipped with refiner plates to free the hulls from the cotyledons. The hulls were then aspirated off. The soybean hulls were kindly supplied by Heimbecker Ltd., Toronto and Celufil, a purified fiber source was obtained from United States Biochemical Corp., Cleveland, Ohio.

Diets. Hulls from rapeseed cultivars, Tower (dark colored) and R500 (yellow colored) and soybean were hammer-milled through a 3.1-mm screen and then included in semipurified diets at a 10% level. Celufil, was also included in one of the diets at a 10% level for comparison. The diets were formulated to meet NRC (1979) requirements. Casein (IFN 5-01-162) was added at a 15% level as the protein source. Dextrose (IFN 4-24-996) and sucrose (IFN 4-04-701) were included at 49 and 21% levels, respectively, as major energy sources. Other dietary ingredients included corn oil (IFN 4-05-078), 1.25%; monodicalcium phosphate (IFN 6-26-137), 1.5%; calcium carbonate (IFN 6-01-069), 1% and salt (iodized; IFN 6-04-151), .5%. Vitamin and mineral premix with a composition described by Mitaru et al. (1984) was added at .25% level. Chromic oxide was included at a level of .5% as an inert marker for digestibility determinations. In order to determine metabolic fecal N, a low protein (maintenance) diet was used in the trial. The composition of the maintenance diet was as described by Sauer (1976) except that dextrose was used in place of cornstarch.

Experimental Design. Four barrows with an average weight of 40 kg and fitted with ileal cannulas were used in a digestibility trial of a 4 × 4 Latin square design. Animals were housed in individual cages with raised slatted floors. Experimental periods were 7 d long and were separated by 4-d rest periods. The maintenance diet was fed in the first and the last periods and the experimental diets were fed in periods two to five. A grower diet was fed during rest periods. Feeding was done three times a day, at 0600, 1400 and 2200 h. At feeding time, each pig was given 750 g of the feed mixed with 375 g of water, at a ratio of 2:1 w/w. A water fountain was installed in each pen to provide cool drinking water at all times. Ileal samples were collected three times in 24 h starting at 1400 h of d 5 and ending at 1400 h of d 6 of each period. Sample collection was accomplished using a double layer plastic bag fastened to the cannula with rubber bands. After 8 h of collection the bags were removed and the samples frozen. This process of sample collection was repeated every 8 h to make three 8-h samples. Fecal collection was made from 1400 h of d 6 to 1400 h of d 7 of each period. Individual animal ileal and fecal samples were clearly identified and frozen. In each experimental period, samples of the diets fed were taken and stored in air-tight plastic containers at 4 C until required for chemical analysis. The ileal and fecal samples were freeze-dried at 38 C shelf temperature. The three daily collections for individual animals in each period were pooled. The pooled samples were ground in a UD 1092 Cyclotec sample mill and stored in air-tight plastic containers until required for chemical analysis. The digestibilities of dry matter, energy, crude protein and amino acids were calculated using standard equations (Lloyd et al., 1978).

Chemical Analysis. The fiber sources and diets were analyzed for proximate components by standard methods (AOAC, 1980). The fiber sources were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HC), cellulose (C) and lignin (ADL) by Van Soest (1963) procedures. The dietary NDF, ADF, HC, C and ADL contents were calculated from the fiber source values. Ileal samples were analyzed for moisture and crude protein and fecal samples were analyzed for energy, moisture and crude protein by the methods of AOAC (1980). Chromic oxide in dietary, ileal and fecal samples was analyzed by the method of Fenton and Fenton (1979). Tannin content in the fiber sources was determined by a modified vanillin-HCl method (Price et al., 1978).

TABLE 1. CHEMICAL ANALYSIS OF TOWER RAPESEED HULLS (TRH), R500 RAPESEED HULLS (RSH), SOYBEAN HULLS (SBH) AND CELUFIL[a]

Component	Fiber sources			
	TRH	RSH	SBH	Celufil
Dry matter (DM), %	89.0	90.5	93.5	94.2
Gross energy, kcal/g DM	5.3	5.4	4.8	4.2
Percentage of DM				
Crude protein, %	15.1	17.4	9.9	.0
Ether extarct, %	10.9	18.8	1.0	.8
Crude fiber, %	39.4	20.0	42.0	72.6
Ash, %	5.1	6.0	4.4	.2
Neutral detergent fiber, %	63.1	39.9	67.0	98.3
Hemicellulose, %	5.8	5.7	15.7	11.3
Acid detergent fiber, %	57.3	34.1	51.2	87.0
Cellulose, %	28.4	28.6	50.0	86.5
Acid detergent lignin, %	28.9	5.5	1.3	.6
Tannin, %[b]	.15	.10	.00	NA[c]

[a]A non-nutritive bulk from United States Biochemical Corp., Cleveland, OH, USA.

[b]Vanillin-HCl determination.

[c]NA = Not analyzed.

For amino acid analyses, the dietary, ileal and fecal samples were finely ground in a Wig L Bug sample mill[7] for 3 min. Ten milligrams of each sample were hydrolyzed with 10 ml of 6N HCl at 110 C for a period of 20 h and the amino acids were determined using a single column Beckman model 119BL amino acid analyzer.

Statistical Analysis. The dry matter, energy, protein and amino acid digestibility data were subjected to analysis of variance for a 4 × 4 Latin square design. The Student-Newman-Keul's (SNK) method (Steel and Torrie, 1960) was used to compare the treatment means after a significant effect was indicated by analysis of variance. Correlation coefficients between various dietary fiber components and dry matter, energy and protein digestibility values were also derived.

Results

Chemical Analysis. Celufil had higher crude fiber (CF), NDF, ADF and C than rapeseed and soybean hulls (table 1). The Tower rapeseed hulls had the highest ADL content (28.9%) while Celufil had the lowest (.6%) value. The R500 rapeseed and soybean hulls had intermediate ADL values (table 1). The extractable tannin content of rapeseed hulls ranged from .1 to .15%. There was no measurable tannin content in the soybean hulls.

Gross energy values of the diets ranged from 4.1 to 4.3 kcal/g dry matter (DM), while the crude protein contents ranged from 13.9 to 15.8% (table 2). Ether extract and crude fiber values ranged from 1.5 to 4.6% and 2 to 7.3%, respectively. Ash content values were from 3.5 to 4.1%. The amino acid content of the diets is shown in table 2. Because casein was the sole protein source used, any minor differences in amino acid concentration in the diets were due to the amino acid contribution of the hull fraction added or to random error of the analysis.

Dry Matter, Protein and Amino Acid Digestibilities at the Terminal Ileum. The dry matter digestibility (DMD) coefficient for the Celufil diet was the lowest of the four diets (table 3). The R500 rapeseed hull (RSH) and Tower rapeseed hull (TRH) diets showed similar and the highest DMD values. The soybean hull (SBH) diet had a lower ($P<.05$) DMD value than the RSH and TRH diets (table 3). The ileal DMD was highly correlated with dietary CF, NDF, ADF, HC and C (table 4). The apparent protein digestibility (APD) value for the TRH diet was the lowest, while that of the Celufil

[7]Crescent Dental MFG Co., Chicago, IL.

TABLE 2. CHEMICAL ANALYSIS OF DIETS

Component[a]	Dietary treatments			
	TRH 10%	RSH 10%	SBH 10%	Celufil 10%
Gross energy, kcal/g	4.2	4.3	4.2	4.1
Crude protein, %	15.8	15.4	15.4	13.9
Ether extract, %	2.7	4.6	1.6	1.5
Crude fiber, %	2.8	2.0	3.8	7.3
Ash, %	4.1	3.9	3.9	3.5
Acid detergent lignin, %[b]	2.89	.55	.13	.06
Dietary indispensable amino acids, %				
Arginine	.60	.56	.59	.49
Histidine	.43	.40	.45	.39
Isoleucine	.78	.72	.83	.72
Leucine	1.46	1.32	1.52	1.33
Lysine	1.23	1.13	1.27	1.07
Methionine	.37	.32	.36	.43
Phenylalanine	.79	.71	.82	.72
Threonine	.72	.63	.68	.58
Valine	1.04	.95	1.06	.93
Dietary dispensable amino acids, %				
Alanine	.50	.46	.53	.42
Aspartic acid	1.20	1.08	1.25	1.12
Cysteine	.08	.07	.07	.04
Glutamic acid	3.55	3.20	3.63	3.16
Glycine	.33	.31	.36	.26
Proline	1.71	1.52	1.70	1.47
Serine	.94	.81	.93	.78
Tyrosine	.86	.79	.92	.71

[a]Dry matter (DM) basis.

[b]Calculated from the acid detergent lignin values of the fiber sources.

diet was the highest (table 3). The RSH and SBH diets had similar and intermediate values. The APD values were highly correlated with the lignin content of the diet (r = −.73). The true protein digestibility (TPD) value (table 3), showed that protein in the TRH diet was the least digestible, while that with the Celufil diet was the most digestible at the ileal level. The values for RSH and SBH were similar and intermediate. There was a highly significant correlation (r = −.60) between the ileal TPD and the lignin content of the diet.

The ileal apparent digestibility values (table 3) for all amino acids except isoleucine, leucine, methionine, phenylalanine, threonine and cysteine were highest with the Celufil diet. The TRH diet showed the lowest digestibility values for arginine, histidine, lysine and alanine. Digestibilities of isoleucine, threonine, valine, aspartic acid, glutamic acid, proline and tyrosine were similar in the TRH and RSH diets, but lower (P<.05) than in the SBH diet. The TRH, RSH and SBH diets showed similar digestibility values for cysteine and serine. The apparent digestibility value of cysteine was lower (P<.05) with Celufil diet than with the hull diets. However, the true digestibility values of cysteine in all the diets were similar with a mean value of 95.5 ± 2.57 (SE). Serine had similar digestibility values in SBH and Celufil diets. Histidine was more digestible with the RSH diet than with the SBH diet, while lysine was more digestible with SBH than with the RSH diet. The digestibility of glycine was higher (P<.05) with the RSH diet than with the TRH and SBH diets. The SBH diet showed a lower (P<.05) digestibility value for glycine than the TRH diet.

Dry Matter, Energy, Protein and Amino Acid Digestibilities Measured Over the Total Tract. The DMD value for the Celufil diet was the lowest (table 5). The RSH and SBH diets gave the highest and similar values while the TRH diet showed an intermediate value. The digestible energy (DE) value of the Celufil diet was the lowest (3.6 kcal/g), while that of

TABLE 3. EFFECT OF TOWER RAPESEED HULLS (TRH), R500 RAPESEED HULLS (RSH), SOYBEAN HULLS (SBH) AND CELUFIL ON DRY MATTER, PROTEIN AND AMINO ACIDS DIGESTIBILITIES MEASURED AT THE TERMINAL ILEUM OF GROWING PIGS

	Dietary treatment				
Component	TRH 10%	RSH 10%	SBH 10%	Celufil 10%	SE[a]
	%				
Dry matter	89.3[d]	89.9[d]	86.7[c]	84.1[b]	.59
Crude protein					
Apparent	85.7[b]	88.2[c]	88.7[c]	92.6[d]	.28
True	91.2[b]	94.0[c]	94.6[c]	98.9[d]	.20
Dietary indispensable amino acids					
Arginine	89.3[b]	91.6[c]	92.1[c]	94.6[d]	.31
Histidine	92.0[b]	94.1[d]	93.2[c]	96.2[e]	.17
Isoleucine	88.2[b]	88.2[b]	91.5[c]	93.4[c]	.54
Leucine	88.2[b]	93.5[b]	94.6[b]	96.2[b]	2.35
Lysine	91.9[b]	92.8[c]	94.3[d]	96.9[e]	.16
Methionine	94.1[b]	94.8[b]	88.3[b]	98.9[b]	4.21
Phenylalanine	90.8[b]	91.4[bc]	93.7[cd]	95.2[d]	.58
Threonine	86.3[b]	87.3[b]	90.6[c]	92.0[c]	.56
Valine	88.2[b]	88.9[b]	91.7[c]	93.9[d]	.31
Dietary dispensable amino acids					
Alanine	82.5[b]	85.0[c]	86.8[d]	89.9[e]	.45
Aspartic acid	87.7[b]	88.8[b]	90.3[c]	93.5[d]	.29
Cysteine	71.2[c]	75.9[c]	71.4[c]	51.4[b]	2.24
Glutamic acid	92.8[b]	92.9[b]	94.2[c]	95.5[d]	.23
Glycine	75.7[c]	78.3[d]	72.5[b]	82.2[e]	.52
Proline	92.8[b]	93.6[b]	95.6[c]	96.7[d]	.23
Serine	84.6[b]	83.5[b]	86.2[bc]	89.0[c]	.87
Tyrosine	88.7[b]	90.1[b]	93.1[c]	95.7[d]	.59

[a]Standard error of the mean.

[b,c,d,e]Means bearing different superscripts in a row differ (P<.05).

the RSH diet was the highest (4.0 kcal/g; table 5). The TRH and SBH diets gave values that were similar and intermediate. The DMD and DE values were highly correlated with the dietary fiber components (table 4).

The APD and TPD values with TRH, RSH, and SBH diets were similar and lower (P<.05) than with the Celufil diet (table 5). There were

TABLE 4. CORRELATION COEFFICIENTS (r) BETWEEN FIBER COMPONENTS AND DRY MATTER AND ENERGY DIGESTIBILITY VALUES

	Dry matter digestibility (%)		
Component	Ileal	Fecal	Digestible energy (kcal/g)
	r		
Crude fiber	−.83**	−.81**	−.63**
Neutral detergent fiber	−.80**	−.86**	−.69**
Acid detergent fiber	−.74**	−.92**	−.71**
Hemicellulose	−.61**	−.08*	−.20*
Cellulose	−.85**	−.72**	−.57**

*P>.05.

**P<.01.

TABLE 5. EFFECT OF TOWER RAPESEED HULLS (TRH), R500 RAPESEED HULLS (RSH), SOYBEAN HULLS (SBH) AND CELUFIL ON DRY MATTER, ENERGY, PROTEIN AND AMINO ACID DIGESTIBILITIES MEASURED OVER THE TOTAL TRACT OF CANNULATED GROWING PIGS

Component	Dietary treatments: TRH 10%	RSH 10%	SBH 10%	Celufil 10%	SE[a]
	%				
Dry matter (DM), %	89.6[c]	92.1[d]	91.4[d]	87.3[b]	.26
Digestible energy, kcal/g DM	3.8[c]	4.0[d]	3.8[c]	3.6[b]	.04
Crude protein, %					
Apparent	89.6[b]	91.6[b]	90.6[b]	94.3[c]	.45
True	95.3[b]	97.3[b]	96.5[b]	100.7[c]	.46
Dietary indispensable amino acids					
Arginine	91.3[b]	93.4[c]	93.0[c]	94.8[d]	.28
Histidine	94.0[b]	95.6[c]	94.7[b]	96.9[d]	.21
Isoleucine	92.5[b]	92.3[b]	92.6[b]	95.3[b]	.63
Leucine	94.4[b]	95.0[b]	95.3[b]	96.7[c]	.23
Lysine	93.8[b]	94.7[b]	94.4[b]	96.3[c]	.19
Methionine	95.6[b]	95.6[b]	97.9[b]	98.6[b]	.53
Phenylalanine	93.0[b]	94.1[b]	94.2[b]	95.6[c]	.28
Threonine	90.2[b]	90.5[b]	92.3[c]	94.4[d]	.27
Valine	92.0[b]	92.6[b]	93.1[b]	95.4[c]	.49
Dietary dispensable amino acids					
Alanine	87.4[b]	88.2[b]	87.5[b]	91.4[c]	.63
Aspartic acid	90.6[b]	91.6[b]	91.6[b]	94.2[c]	.43
Cysteine	75.5[b]	85.6[b]	79.6[b]	67.7[b]	3.34
Glutamic acid	95.8[b]	95.4[b]	95.5[b]	97.1[b]	.36
Glycine	81.5[bc]	84.2[b]	79.0[c]	87.9[d]	.70
Proline	95.2[b]	96.4[c]	97.0[c]	98.1[d]	.23
Serine	91.8[b]	90.6[b]	90.2[b]	94.3[c]	.68
Tyrosine	92.9[b]	93.6[bc]	94.1[c]	95.4[d]	.20

[a]Standard error of the mean.

[b,c,d]Means bearing different superscripts in a row differ (P<.05).

highly significant negative correlations (r = −.59; r = −.64) between dietary ADL, and APD and TPD values, respectively.

The Celufil diet showed the highest apparent digestibility values for arginine, histidine, leucine, lysine, phenylalanine, threonine, valine, alanine, aspartic acid, glycine, proline, serine and tyrosine (table 5). The TRH diet showed the lowest digestibilities for arginine and proline. Digestibility values for isoleucine, methionine, cysteine and glutamic acid were similar in all the diets. Leucine, lysine, phenylalanine, valine, alanine, aspartic acid and serine showed similar digestibilities in TRH, RSH and SBH diets, respectively.

Histidine was more digestible (P<.05) with the RSH diet than with TRH and SBH diets, while threonine was more digestible (P<.05) with the SBH diet than with the TRH and RSH diets. Glycine was less digestible (P<.05) with the RSH diet as compared with the SBH diet, although it was not different (P>.05) from the TRH diet. The RSH and SBH diets showed similar digestibility values for arginine, proline and tyrosine. The digestibility values for tyrosine in TRH and RSH were not different (P>.05).

Comparison of Digestibility Values Measured at the Terminal Ileum and Over the Total Tract. To compare the collection sites (terminal ileum and total tract) the digestibility data across all treatments were combined. The dry matter and protein digestibility values at the terminal ileum were lower (P<.01) than the corresponding values measured over the total tract (table 6). All the amino acids except leucine, lysine and methionine had higher (P<.01) apparent digestibility values at the fecal level than at the ileal level (table 6). Ileal apparent digestibility values for leucine and lysine were lower (P<.05)

TABLE 6. COMPARISON OF THE DRY MATTER, PROTEIN AND AMINO ACID DIGESTIBILITIES MEASURED AT THE TERMINAL ILEUM AND THE TOTAL DIGESTIVE TRACT OF THE PIGS IN THE TRIAL

Component	Terminal ileum	Total tract	SE[a]	Difference[b]
	%			
Dry matter	87.4	90.0	.36	2.6**
Crude protein				
Apparent	88.8	91.5	.25	2.7**
True	94.7	97.4	.41	2.7**
Dietary indispensable amino acids				
Arginine	91.9	93.1	.25	1.2**
Histidine	93.8	95.3	.14	1.5**
Isoleucine	90.5	93.3	.35	2.8**
Leucine	93.1	95.4	.90	2.3*
Lysine	94.0	94.8	.22	.8*
Methionine	94.0	97.0	3.51	.3
Phenylalanine	92.9	94.2	.28	1.3**
Threonine	89.2	91.9	.29	2.7**
Valine	90.8	93.3	.27	2.5**
Dietary dispensable amino acids				
Alanine	86.1	88.6	.40	2.5**
Aspartic acid	90.2	92.0	.26	1.9**
Cysteine	66.9	76.5	1.44	9.6**
Glutamic acid	93.9	96.0	.19	2.1**
Glycine	77.1	83.1	.42	6.3**
Proline	94.7	96.7	.18	2.0**
Serine	86.0	91.8	.53	5.8**
Tyrosine	92.0	94.0	.43	2.02**

[a]Standard error of the mean.

[b]Total tract minus ileal digestibility.

*P<.05.

**P<.01.

than the corresponding values at the fecal level while the methionine values at ileal and fecal levels were not different (P>.05; table 6).

Discussion

The dry matter and energy digestibility values were shown to be inversely related to CF, NDF, ADF and C. Hemicellulose showed a significant correlation with ileal dry matter digestibility, but not with dry matter digestibility or digestible energy measured along the total digestive tract. The dietary fiber component represents the unavailable carbohydrate portion of the diet and as this portion increases, the digestibility of energy is decreased (Southgate and Durnin, 1970).

The protein and amino acid digestibilities were not adversely affected by C content of the diets as demonstrated by the Celufil diet, which showed the highest digestibility values for protein and majority of the amino acids despite its higher C content (8.7%), compared with the hull diets (2.8 to 5%). However, lignin seems to have had a deleterious effect on protein and amino acid digestibility values. The significant correlation between protein digestibility and the dietary lignin content supports this finding. Begner et al. (1975) and Meir and Poppe (1979) have reported that fibers due to their lignification, are capable of adsorbing amino acids and thus withholding them from absorption. Studies of Shah et al. (1982) and Nomani and Stansberry (1982) have also shown that lignin has a detrimental effect on protein digestibility. Lignin is a polymer of phenyl propyl alcohols and acids, is insoluble and hydrophobic in nature (Shah et al., 1982). The lowering of protein digestibility by lignin may be due to hydrophobic binding of amino acids.

The case for the adverse effect of rapeseed hull lignin on protein digestibility is complicated by a higher content of nonlignin polyphenols (tannin type) in ADL value of dark hulls as compared to yellow hulls (Theander et al., 1977). The extractable tannin content of the rapeseed hulls is low (.1 to .15%) and probably may not lower the protein digestibility values. However, the effects of the unextractable rapeseed hull tannin (which forms a part of ADL) on protein digestibility is not known.

Other factors in the hulls may be partly responsible for the lowering of protein and amino acid digestibility values. Gel-forming polysaccharides, for example pectin, which is a component of plant fiber (Eastwood, 1973) have been reported to impair protein hydrolysis in the intestines (Murray et al., 1977). Pectin forms a viscous gel-matrix that may decrease accessibility of protein molecules held in the matrix to the digestive enzymes and of the products of digestion to the absorptive sites.

Dietary fiber may have an adverse effect on the protein and amino acid digestibilities because of its physio-chemical properties (Southgate, 1973). Any reduction in the intestinal transit time associated with fiber containing diets could also leave less time for digestion and absorption of dietary protein (Burkitt et al., 1972; Eastwood, 1973). The possibility that fiber might increase the sloughing of intestinal mucosal cells leading to increased losses of endogenous N has been suggested (Begner et al., 1975; Sheard and Schneeman, 1980).

Comparison of the collection sites showed that the fecal dry matter, protein and amino acid digestibilities are higher than the corresponding ileal values. The disappearance of nutrients in the hindgut has also been documented by other researchers (Cho and Bayley, 1972; Sauer et al., 1977; Rerat, 1978).

In this study we have demonstrated that cellulose can be included in pig diets up to 9% without a deleterious effect on protein and amino acid digestibilities, although this level will lower energy digestibility. Lignin and other undetermined factors in the hulls have adverse effects on protein and amino acid digestibilities in the pig. The TRH (dark) had a more adverse effect on protein digestibility than the RSH (yellow) and SBH.

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