Digestion of Protein in the Small and Large Intestines of Equines Fed Mixed Diets

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Summary

It appears that in all these experiments with equines fed mixed diets the true digestibility of nitrogen in the small intestine ranged from 45–80 % and that in the large intestine was 80–100 %. Further, it is concluded that 50–70 % of the digestible protein was digested in the small intestine. Further work is needed on a wider variety of feedstuffs, but the implications of these and earlier observations are that the formulation of rations to supply amino acids to horses with high protein requirements must take into account the site of digestion of specific feed proteins.

Verdauung von Protein im Dünn- und Dickdarm von Pferden

In den bisherigen Untersuchungen mit Pferden, die Mischfutter erhielten, scheint die wahre Verdaulichkeit des Stickstoffes im Dünndarm zwischen 40 und 80 Prozent und im Dickdarm zwischen 80 und 100 Prozent zu liegen. Von dem verdauten Rohprotein werden 50 – 70 Prozent im Dünndarm verdaut. Weitere Arbeiten mit einer größeren Futtermittelauswahl sind notwendig, aber aus dieser und früheren Untersuchungen kann gefolgert werden, daß bei der Rationsgestaltung von Pferden mit hohem Proteinbedarf zur Sicherung einer ausreichenden Aminosäurenvergärung der Ort der Proteinverdauung im Verdauungskanal für die verschiedenen Eiweißfuttermittel beachtet werden muß.

The equine has the capability for both enzymatic digestion of protein in the small intestine and fermentive digestion of protein in the large intestine. The extent to which a given dietary protein is digested in the small or large intestine affects the biological value of that protein for those equines that have high protein requirements. The end result of enzymatic protein digestion in the small intestine is the absorption of a profile of amino acids that is reflective of the available amino acid profile in the dietary protein, while the end result of fermentive protein digestion in the large intestine is the production of ammonia with no effective absorption of essential amino acids. The digestibility of a wide range of proteins that pass through the total digestive tract of the equine appears to be very similar, even though the biological value of those proteins may be very different. Thus, *NRC* (1989) abandoned the futile use of total-tract digestible protein as a measure of differences in the nutritional value of feed proteins for the equine. Research in this laboratory has been focused on determining the relative digestibility of forage, cereal, and oil-seed proteins in the small and large intestines of the equine. *Gibbs* et *al.* (1988) reported on digestion of forage proteins, and some of the other data on digestion of proteins in mixed diets have been reported abstractly (*Haley* et *al.*, 1979; *Klendshoj* et *al.*, 1979; *Gibbs* et *al.*, 1983). This paper presents remaining data and a summary of this long-term research project.

Experimental procedures

The basic technique used in these studies was that of sequential sampling of feed, ingesta and feces from horses and ponies fitted with permanent posterior ileal cannulas. The animals were meal-fed varying amounts, sources and forms of protein in conventional hay and grain diets. Procedures for installing the ileal cannulas were described by *Householder* (1978). Chromic oxide was fed as an external indicator in all experiments. The basic approach was to feed the animals assigned diets in Latin square or switchback arrangements such that all animals received all experimental diets. Experimental periods were composed of adjustment periods of 10–14 days and sampling periods of 4–7 days. In the sampling periods, fecal grab samples were obtained at each 2 hours during the interfeeding interval. Ileal samples were generally collected at each 30-min. interval for 2–3 hours following feeding then each 2-hr. interval during the remainder of the interfeeding interval. Samples were composited to provide one sample of ileal contents and one sample of feces for each animal on each diet treatment. Nitrogen concentrations in feed, ileal contents and feces were determined by Kjeldahl procedures, and chromium concentrations in those samples were determined colorimetrically following acid oxidation. Digestion of nitrogen in different segments of the digestive tract was determined from changes in nitrogen: chromium ratios. Data were analyzed by analyses of variance appropriate for the Latin square design, and when treatment effects were significant, differences between means were identified by *Duncan's* multiple range test. Least squares regression analyses were also used to estimate true protein digestion coefficients.

Results and discussion

Digestion of total dietary nitrogen-mixed diets

Samples from another study (*Householder,* 1978) were analyzed to determine prececal and postileal digestibility of nitrogen in 370-kg horses fed a diet with a 50 : 50 ratio of bermudagrass hay and concentrates. Approximately two thirds of the dietary protein was supplied by the concentrate portion of the diet, and approximately two thirds of the protein in the concentrates was supplied by oats or

Table 1: Nitrogen digestion in the small and large intestines of horses fed oats or sorghum grain-crimping vs. micronizing

	diet treatment					
	CO[a]	MO[b]	CS[c]	MS[d]	Mean	SE
N Intake[e]	130	132	138	130	132	2.6
Total digested[e]	89	94	86	85	88	2.6
% of intake	68.6[gh]	70.9[h]	62.2[f]	65.1[fg]	66.7	1.3
Prececal digested[e]	60	47	70	67	61	5.4
% of intake	45.4	35.9	51.5	52.0	46.2	4.1
Ileal N[e]	70	86	67	63	71	5.7
Postileal digested[e]	29[fg]	47[g]	15[f]	18[f]	27	6.2
% of ileal	38.6	51.6	18.7	14.6	30.9	7.6
Relative digestion, %						
Prececal	66.1[g]	50.6[f]	84.0[g]	80.5[g]	70.3	6.9
Postileal	33.9[fg]	49.4[f]	16.0[g]	19.5[g]	29.7	6.9

[a] Crimped oats; [b] micronized oats; [c] crimped sorghum; [d] micronized sorghum; [e] mg/kg body weight/feeding; [f,g,h] means in the same row not sharing the same superscript differ ($P<.05$)
From *Klendshoj* (1979)

sorghum grain that was crimped or "micronized" (dry-heated, rolled). The remaining protein in the concentrates was supplied by a soybean meal-based supplement. As seen in table 1, nitrogen intake was similar across treatments, but apparent digestibility of nitrogen over the total digestive tract was lowest when the horses were fed the crimped sorghum diet and highest when they were fed the micronized oats diet. This effect was apparently due to a poorly digestible fraction of the dietary protein reaching the large intestine when the horses were fed sorghum because prececal digestion of nitrogen in the sorghum diets was a high or higher than that in the oats diets. Postileal digestion of nitrogen from the sorghum diets that reached the ileum appeared to be very low. However, the effects of metabolic fecal protein may have caused the apparently low postileal nitrogen digestibility of the sorghum-based diets because regression of postileal nitrogen digestion on ileal nitrogen revealed that the true postileal nitrogen digestibility was over 90 %. On the average, it appeared that 70 % or more of the digestible protein was digested in the small intestine of these horses fed mixed diets, compared to 35 % or less in the forage-fed ponies of *Gibbs* et *al.* (1988).

In another experiment, concentrate diets based on oats supplemented with soybean meal or cottonseed meal were fed to ileal cannulated horses, weighing 385 kg, in a 50 : 50 ratio with bermudagrass hay. The concentrate portion of the supplemented diets supplied approximately two thirds of the total dietary protein, and approximately 20 % of the protein in the supplemented concentrates was supplied by soybean meal or cottonseed meal. As seen in table 2, adding soybean or cottonseed meal nitrogen to the basal oats diet resulted in near quantitative increasess in apparent total tract and prececal nitrogen digestion with no increase in nitrogen reaching the ileum. This observation indicates that the true digestibility of the soybean and cottonseed meal proteins in the small intestine was near 100 %. Apparent digestibility of ileal nitrogen in the large intestine appeared lower than prececal digestibility, but again this was due to the effects of metabolic fecal protein. Regression of postileal nitrogen digested on ileal nitrogen revealed that the true postileal digestibility of nitrogen was near 100 %. As in the previous experiment, approximately 70 % of the digestible protein was digested in the small intestine.

Digestion of cereal and oil-seed proteins

Data from the previous experiments and that of *Gibbs* et *al.* (1988) indicated that the site of protein digestion was apparently different for different sources of protein in equine diets. Thus, stepwiese experiments were conducted to determine the site and extent of digestion of cereal and oil-

Table 2: Nitrogen digestion in the small and large intestines of horses fed oats and supplemental soybean meal and cottonseed meal

	diet treatment				
	Basal	SBM	CSM	Mean	SE
N Intake[a]	143	153	161	152	3.6
Total digested[a]	98	111	116	109	4.2
% of intake	68.0	72.6	72.6	71.1	1.2
Prececal digested[a]	66	78	88	77	6.5
% of intake	46.1	50.6	54.3	50.4	3.2
Ileal N[a]	77	75	72	75	4.2
Postileal digested[a]	32	33	28	31	4.7
% of ileal	40.1	44.1	34.8	39.7	4.7
Relative digestion, %					
Prececal	67.3	70.3	75.9	70.6	4.4
Postileal	32.7	29.7	24.1	28.4	4.4

[a] mg/kg body weight/feeding
From *Haley* (1981)

Table 3: Digestion of grain nitrogen in the small and large intestines of ponies fed corn, oats and sorghum

	source of grain				
	corn	oats	sorghum	mean	SE
N Intake[a]	68[b]	102[c]	68[b]	79	0.8
Total digested[a]	66[b]	90[c]	63[b]	73	1.3
% of intake	98.1	88.5	93.1	92.6	1.2
Prececal digested[a]	32	55	48	45	4.4
% of intake	48.1	53.9	70.7	57.1	4.5
Ileal N[a]	41	47	20	36	4.1
Postileal digested[a]	34	35	15	28	5.6
% of ileal	81.3	75.1	76.6	77.7	11.7
Relative digestion, %					
Prececal	49.0	60.9	75.9	61.6	5.9
Postileal	51.0	39.1	24.1	38.4	5.9

[a] mg/kg body weight/feeding
[b, c] means is the same row not sharing same superscript differ ($P<.05$)
From *Gibbs* (1982)

Table 4: Digestion of concentrate nitrogen in the small and large intestines of ponies fed corn and supplemental soybean meal and cottonseed meal

	Source of concentrate nitrogen				
	corn	corn & SBM	corn & CSM	mean	SE
N Intake[a]	45[b]	128[c]	117[c]	97	1.0
Total digested[a]	44[b]	121[d]	105[c]	90	1.0
% of intake	96.9[b]	94.2[b]	89.7[c]	92.8	0.3
Prececal digested[a]	19[b]	62[c]	77[c]	52	1.3
% of intake	41.0	48.4	65.2	54.1	4.3
Ileal N[a]	27[b]	66[d]	41[c]	45	1.3
Postileal digested[a]	25[b]	59[c]	29[b]	38	0.7
% of ileal	94.7[b]	88.7[b]	70.6[c]	84.4	1.1
Relative digestion, %					
Prececal	42.3	51.4	72.7	58.3	4.4
Postileal	57.7	48.6	27.3	41.7	4.4

[a] mg/kg body weight/feeding
[b, c, d] means in the same row not sharing the same superscript differ ($P<.05$)
From *Gibbs* (1982)

seed proteins fed in high-concentrate diets to ponies. A by-difference technique was used to estimate digestion of the cereal and oil-seed proteins. Coastal bermudagrass hay from the same source as that fed by *Gibbs* et *al.* (1988) was fed in these experiments. To minimize potential associative effects, hay was limited to 25 % of the diet. It was assumed that the site and extent of digestion of hay protein was the same as that reported by *Gibbs* et *al.* (1988). In the first experiment, corn, oats, and sorghum grain were fed to 135-kg ponies as the sole source of protein other than that from hay. The cereal proteins supplied 75 % of the protein in the total diet. Digestion of cereal protein was determined as the difference between digestible protein from the total ration minus the digestible protein from hay. As seen in table 3, apparent digestion coefficients were very high and probably reflect true digestibility because effects of metabolic fecal protein were partially removed in the by-difference calculations. There was no difference in the apparent digestibility of protein from corn, oats, or sorghum grain over the whole digestive tract or in either segment of the digestive tract, even though it appeared that the prececal digestion of sorghum protein may have been highest. Regression analyses indicated that the true digestibility of cereal nitrogen in the large intestine was approximately 80 %, but large variation prevented a reasonable estimate of true digestion in the small intestine. However, it should be noted that compared to earlier experiments, it appeared that relatively less of the digestible protein was digested in the small intestine in this experiment (average 62 %) compared to earlier experiments in which concentrate diets contained other sources of protein.

In the second experiment, corn was chosen as the carrier concentrate and soybean meal or cottonseed was added to the concentrate. In these diets, at least 50 % of the total dietary protein was supplied by the oil-seed proteins. Digestion of the concentrate nitrogen was estimated by difference, and digestion of the oil-seed protein was determined by regression of digested amount on that available for digestion. As seen in table 4, adding soybean meal or cottonseed meal to the concentrate resulted in significant increases in prececal and total tract digestion of protein, and nitrogen reaching the ileum. The concentrate containing cottonseed meal appeared to be more digestible in the small intestine soybean meal. The regression of prececal concentrate nitrogen digested on concentrate nitrogen intake indicated that the estimated true prececal digestiblity of the cottonseed meal protein was 78 % while that for soybean meal was 52 %. The regression of postileal concentrate nitrogen digested on concentrate nitrogen reaching the ileum indicated that postileal digestion of nitrogen from both diets was approximately 90 %

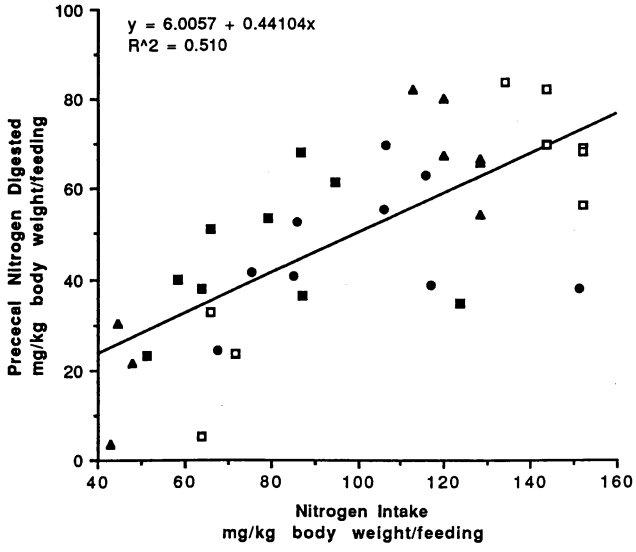

Fig. 1: Prececal nitrogen digested at varying nitrogen intakes.

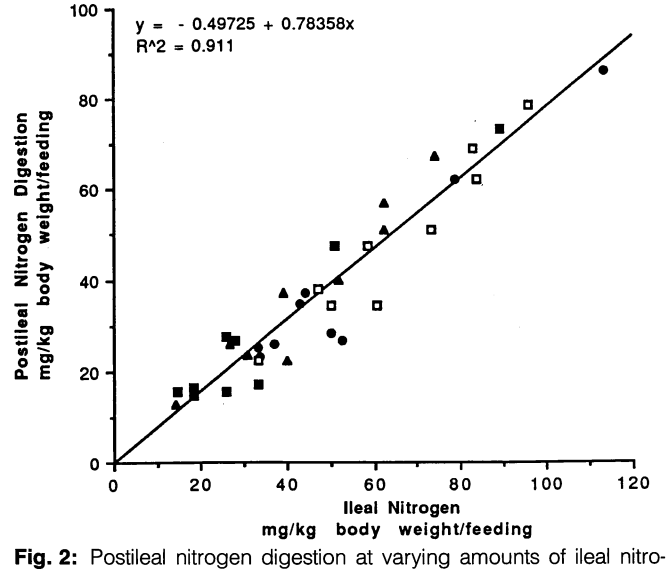

Fig. 2: Postileal nitrogen digestion at varying amounts of ileal nitrogen.

Estimates of true digestibility

Data from these and previous experiments indicate that digestion of different sources of protein in the small intestine of equines fed mixed diets is quite variable, perhaps due to the relative proportions of albumin-type vs. zein-type proteins in various feedstuffs. However, it appears that fermentive digestion of proteins in the large intestine is quite extensive regardless of the source of protein. In each of these experiments, estimates of the true digestibility of proteins over the total tract and in the large intestine were 80 – 100 %, but data in some experiments were too variable to estimate the true digestibility of proteins in the small intestine. Thus, data from four experiments in which there was reasonable variation in nitrogen intake were combined to provide an overall estimate of the true digestiblity of proteins in the small and large intestines. The regression of prececal nitrogen digestion on nitrogen intake and postileal nitrogen digestion on nitrogen reaching the ileum are shown in figures 1 and 2. Over this array of sources of protein, it appears that the average prececal digestibility of nitrogen was near 45 % and the average postileal digestibility of nitrogen was near 80 %.

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