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DIGESTION COEFFICIENTS, BLOOD GLUCOSE LEVELS AND MOLAR PERCENTAGE OF VOLATILE ACIDS IN INTESTINAL FLUID OF PONIES FED VARYING FORAGE-GRAIN RATIOS¹

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THE effects of varying forage-grain ratios have been extensively studied in ruminants but not in horses. However, recent studies indicate that varying the forage-grain ratio can change the site and end products of digestion in the horse (Hintz *et al.*, 1971, Stillions, Teeter and Nelson, 1970). The following trials were conducted to provide additional information on the effect of varying forage-grain ratios on digestibility, molar percentages of VFA in intestinal fluid and blood glucose levels in ponies.

Experimental Procedure

Trial 1. Twelve mature ponies (avg wt 131 kg) were fed diets containing forage—grain ratios of 1:0, 3:2 or 1:4 (table 1) at the rate of 2.1 kg, 1.9 kg and 1.65 kg/100 kg of body weight, respectively. These amounts were calculated to supply about 160 kcal of DE/kg $\frac{3}{4}$ of body weight. Venous blood samples were taken for glucose analysis (Dubowski, 1962) 30 min. prior to feeding and 1, 3, 5 and 7 hr. after feeding on 3 successive days after the ponies had been fed the diets for 24 days. The animals were killed by an overdose of sodium pentobarbitol after 30 days. The entire digestive tract was removed and segments were isolated. Samples of contents from the cecum and from the ventral large colon were strained through cheesecloth. Mercuric chloride was added as a preservative and the fluid was frozen at -20°C until analysis for VFA by gas chromatography. The contents of the small colon and rectum were freeze-dried and analyzed for Kjeldahl nitrogen, neutral detergent fiber (Van Soest and Wine, 1965) available carbohydrate (D_{20} method of Friedmann *et al.*, 1967) and chromic oxide (Bolin and King, 1952). Digestion coefficients were determined by use of the Cr_2O_3 : nutrient ratios (Maynard and Loosli, 1962).

Trial 2. Three mature ponies (avg wt. 163

kg) fitted with cecal fistulas (Lowe, Hintz and Schryver, 1970) were used in a 3 x 3 latin square design experiment. Timothy hay, 50% hay and 50% shelled corn or 20% hay and 80% shelled corn were fed at a rate of 1.6 kg/100 kg of body weight. The diets were calculated to supply 108, 155 and 160 kcal of DE/kg $\frac{3}{4}$. Trace mineralized salt was available *ad libitum*. Feces and urine were collected for 7 days after a period of at least 3 weeks. Venous blood samples were obtained on the fourth, fifth and sixth days of the collection period 30 min. prior to and 1, 3 and 5 hr. after the morning feedings. Samples of cecal fluid were taken on the same days 30 min. prior to and 2 and 5 hr. after the morning feeding.

Results

The digestibility of dry matter, available carbohydrate, fiber and crude protein of grain was significantly greater than that of forage (table 2). However the relation between percent of nutrient fraction in the diet supplied by forage and the digestibility of that nutrient fraction was linear, demonstrating that there were no interactions or associative effects.

Plasma glucose levels varied with time after feeding but were not affected by the type of diet in either trial (table 3). The total concentration of VFA in cecal fluid of ponies fed the high forage diet was greater than that of ponies fed the high grain diet. Moreover, the high grain diet produced a lower percentage of acetate and higher percentages of propionate, isovalerate and valerate (table 4). The percentage of butyrate was significantly ($P < .05$) higher in the cecal fluid of ponies fed the high grain or medium grain diets than in ponies fed the all hay diet in trial 2 but not in trial 1. The total concentration of VFA in colic fluid from ponies fed the high grain diet was lower than for the other diets ($P < .05$). However the molar percentages of VFA in colic fluid were not affected by diet. The per-

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TABLE 1. INGREDIENTS OF THE EXPERIMENTAL DIETS (TRIAL 1)

Ingredient	Forage-grain ratio		
	1:0	3:2	1:4
Alfalfa meal, dehydrated	98.3	59.0	19.6
Ground corn	....	31.5	63.0
Soybean meal	....	7.8	15.7
Salt, trace mineral ^a	1.0	1.0	1.0
Cr ₂ O ₃	0.7	0.7	0.7

^a Sterling Blusalt, International Salt Co., Clarks Summit, Pa. Contains not less than 0.20% Mn; 0.15% Fe; 0.10% Mg; 0.05% S; 0.03% Cu; 0.01% Co; 0.008% Zn and 0.007% I.

centage of isovalerate in colic fluid was greater than that in cecal fluid. Samples of fluid taken via cecal fistula at 30 min. prior to and 2 and 5 hr. after feeding contained similar percentages of VFA (table 5). The ponies maintained body weight in trial 1 and ponies fed the 1:4 or 1:1 diets in trial 2 maintained body weight but lost about 0.5 kg/day when fed the 1:0 diet.

Discussion

Our trials failed to demonstrate a significant associative effect due to forage-grain ratio or a decreased digestibility of forage because of the addition of grain. Changing the forage-grain ratio from 1:0 to 1:4 did not decrease the digestibility of forage by ruminants (Moe, Reid and Tyrrell, 1965; Vidal *et al.*, 1969) although the addition of highly soluble sugars, such as glucose, to forage did (Mitchell, Hamilton and Haines, 1940). Moreover, Winkler

TABLE 3. EFFECT OF FORAGE-GRAIN RATIO ON BLOOD GLUCOSE LEVELS OF PONIES

Forage-grain ratio	Time after feeding (hours)						
	Trial 1						
	-½	½	1	3	5	7	
1:0	85.0	....	104.5	102.0	95.9	87.1	
3:2	84.5	....	107.2	109.1	94.2	87.6	
1:4	87.7	....	104.0	110.4	90.7	85.4	
	Trial 2						
1:0	87.1	98.3	103.4	99.6	87.1	....
1:1	89.0	98.2	103.4	100.0	89.6	....
1:4	92.0	103.5	107.0	101.4	85.4	....

(1941) reported that the addition of high levels of grain did not decrease the fiber digestibility of alfalfa or meadow hay by horses. However, Lindsey, Beals and Archibald (1926) reported that the digestibility of the crude fiber of a 50% alfalfa hay—50% corn diet by horses was lower than that of only alfalfa hay and suggested that fiber digestibility was influenced by the ingredients in the diet.

Plasma glucose levels were not influenced by forage-grain ratios even when intakes were at sub-maintenance levels suggesting that differences in glucogenic properties of the diets can be compensated for by hormonal action. Topps, Kay and Goodall (1968) reported that feeding high levels of grain did not affect plasma glucose levels in sheep. Crawford, Baker and Lieb (1969) reported that the forage-grain ratio did not influence plasma glucose levels when horses were fed diets adequate in energy. However, they found at in-

TABLE 2. COMPOSITION AND APPARENT DIGESTIBILITY OF DIETS

Forage-grain-ratio	Dry matter	Crude protein	Neutral detergent fiber	Acid detergent fiber	Cellulose	Available carbohydrate
Composition—Trial 1						
1:0	90.9	19.0	41.6	....^d	....	9.1
3:2	91.0	17.5	34.4	....	....	22.4
1:4	90.3	16.9	19.5	....	....	43.4
Composition—Trial 2						
1:0	90.0	7.0	61.5	36.5	28.0	....
1:1	89.9	8.2	37.5	20.2	15.4	....
1:4	90.1	8.8	23.0	10.4	7.7	....
Digestibility—Trial 1						
1:0	55.5 ^a	70.5 ^a	41.2 ^a	....	....	90.7 ^a
3:2	69.7 ^b	75.5 ^{a, b}	54.8 ^b	....	....	97.7 ^b
1:4	79.7 ^c	79.8 ^b	56.9 ^b	....	....	99.1 ^b
Digestibility—Trial 2						
1:0	51.6 ^a	42.6 ^a	47.5 ^a	40.5 ^a	45.3 ^a	....
1:1	73.8 ^b	64.9 ^b	59.0 ^b	47.2 ^b	53.5 ^b	....
1:4	82.2 ^b	80.5 ^c	71.2 ^c	60.0 ^c	63.4 ^c	....

^{a, b, c} Values with different superscripts significantly different (P<.05).
^d Dashes indicate these components were not determined.

TABLE 4. EFFECT OF FORAGE-GRAIN RATIO ON MOLAR PERCENTAGE OF VOLATILE FATTY ACIDS

Forage-grain ratio	Acetate	Propionate	Iso-butyrate	Butyrate	Iso-valerate	Valerate	Total mM/l
Cecal fluid—Trial 1							
1:0	76.2 ^a	14.8	0.3	8.0	0.2 ^a	0.5 ^a	57.3 ^a
3:2	70.4 ^b	21.2 ^b	0.2	7.2	0.2 ^a	0.8 ^{a, b}	51.7 ^{a, b}
1:4	61.2 ^c	26.0 ^c	0.5	10.2	0.9 ^b	1.2 ^b	47.8 ^b
Colic fluid—Trial 1							
1:0	69.5	16.2	2.7	7.6	3.1	0.9	41.8 ^a
3:2	68.2	15.0	2.9	8.8	3.9	1.2	47.6 ^a
1:4	67.0	17.0	2.5	9.0	3.6	1.1	28.4 ^b
Cecal fluid—Trial 2							
1:0	70.7 ^a	19.4 ^a	0.5	8.7 ^a	0.4 ^a	0.3 ^a	41.0
1:1	69.3 ^a	18.0 ^a	0.6	11.2 ^b	0.5 ^a	0.4 ^a	40.5
1:4	57.6 ^b	24.2 ^b	0.9	12.5 ^b	3.0 ^b	1.8 ^b	37.2

^{a, b} Values with different superscripts significantly different ($P < .05$).

takes below maintenance the plasma glucose levels were lower in horses fed only hay than in horses fed only oats.

The changes in molar percentage of VFA in cecal fluid were similar to those reported by Stillions *et al.* (1970) in horses and to those produced in rumen fluid by altering forage-grain ratios (Annison and Armstrong, 1969). The fact that increasing the grain intake produces a change in VFA ratio of cecal fluid indicates that some of the undigested starch enters the cecum. It has previously been shown that although the small intestine is the primary site of soluble carbohydrate disappearance, some soluble carbohydrate enters the cecum (Hintz *et al.*, 1971).

Further studies are needed to determine the nutritional significance of altered VFA ratios in the cecum but it appears that the relative importance of substrates can be changed in the horse by changing the forage-grain ratio. A high grain diet results in greater carbohydrate disappearance from the small intestine and therefore probably greater glucose absorption (Hintz *et al.*, 1971) and a relatively higher percentage of propionate, a glucogenic substance, is produced in the cecum when a high grain diet is fed.

TABLE 5. EFFECT OF TIME AFTER FEEDING ON MOLAR PERCENTAGE OF VOLATILE FATTY ACIDS IN CECAL FLUID (TRIAL 2)

Time after feeding (min.)	Acetate	Propionate	Iso-butyrate	Butyrate	Isovalerate	Valerate
—30	64.8	21.1	0.9	11.0	1.1	1.1
120	64.9	21.1	0.8	10.7	1.7	0.8
300	67.8	19.1	0.5	10.7	1.1	0.8

The forage-grain ratio did not affect percentages of VFA in colic fluid which supports previous studies that indicated that only small amounts of soluble carbohydrate reached the colon even when high grain diets were fed (Hintz *et al.*, 1971).

The most significant effects of varying the forage-grain ratios in horses appear to be changing the site of and the end products of digestion. Interactions or associative effects on digestibility appear to be of little practical concern when feeding typical grains and forages. Ponies can maintain similar plasma glucose levels when fed varying forage-grain ratios.

Summary

Two trials were conducted in which ponies were fed varying forage-grain ratios to study the effects of the various ratios on digestibility, molar percentages of volatile fatty acids (VFA) in intestinal fluid and blood glucose levels in ponies. No interactions or associative effects on digestibility due to forage-grain ratio were observed. Blood glucose levels were not influenced by the forage-grain ratio. The total concentration of VFA in cecal fluid and the percentage of acetate was decreased and the percentages of propionate, isovalerate and valerate were increased when high grain diets were fed.

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