Fiber Digestion and Weight Gain in Guinea Pigs Fed Diets Containing Different Fiber Sources

Ei SAKAGUCHI¹⁾, Hiroshi ITOH²⁾, Tsuyoshi KOHNO¹⁾,
Seinosuke OHSHIMA²⁾, and Kiyoshi MIZUTANI²⁾

¹⁾Faculty of Agriculture, Okayama University, Tsushima-naka 1-1-1, Okayama 700 and

²⁾Research Center, Nihon Nosan Kogyo K.K., 5246 Takura, Tsukuba-shi, Ibaraki 300-33, Japan

Abstract: The effects of different fiber sources on feed intake, weight gain and digestibility of fiber were examined in guinea-pigs fed pelleted diets containing alfalfa meal, oaten hay, beet pulp and commercial hay cubes mixed with a basal diet at ratios of 3:1 (75% in the diet), 1:1 (50%) and 1:3 (25%). The basal diet contained 50.0% corn, 4.1% wheat, 22.1% wheat flour and 17.7% corn gluten meal. Food intake increased as the amount of fiber source was increased, but not in the case of beet pulp. The most digestible fiber (ADF and NDF) was that of beet pulp. Apparent digestibility of dry matter decreased with increasing ratios of fiber source to the basal diet for all fiber sources, but fiber and crude protein digestibilities varied and depended not only on the ratio of fiber to the basal diet but also on the source of the fiber.

Key words: digestibility, fiber sources, guinea pig, weight gain

Introduction

The guinea-pig (*Cavia porcellus*) is a small (0.7–1.5 kg) herbivorous mammal with a simple stomach but a voluminous cecum [22], and is more efficient in the digestion of fiber than rabbits, hamsters and rats [23]. It has been reported that on the same diet, guinea-pigs digest organic matter and crude fiber to the same extent as do horses and ponies [26]. Liquid and particulate digesta move at similar rates through the gastrointestinal tract of the guinea-pig, and there is no selective retention of either phase of digesta in its hindgut, which probably explains why fiber digestion is so high in such a small animal [16].

Hirsh (1973) reported that the guinea-pig was relatively insensitive to caloric density of diets containing cellulose in different concentrations [15]. The cecum of the guinea-pig contains concentrations of short-chain fatty acids (SCFAs) similar to those in the bovine rumen [14, 21]. The SCFAs produced in the cecum have been estimated to be equivalent to 31% of the animal's basal metabolic rate [21]. These findings suggest that the guinea pig has a relatively high ability to derive energy from fibrous materials.

It has long been recognized that fiber is an important ingredient in the diet of the guinea-pig [7, 13], but evaluation of the feeding value of different sources of fiber to the guinea pig has been limited so far. Alfalfa

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Address corresponding: E. Sakaguchi, Faculty of Agriculture, Okayama University, Tsushima-naka 1-1-1, Okayama 700, Japan

meal, oaten hay and hay cube are forage crops commonly used as the primary feeds for herbivorous animals. Beet pulp is the dried residue remaining after extraction of sugar, and is an important source of protein and energy to ruminants. These forages and residual plant material are considered to be useful fiber sources for feeding to guinea pigs.

The objective of the present study was to compare the intake, digestibility and utilization of diets containing different fiber sources and the effect of different ratios of each fiber source in a common basal diet on the feed intake and digestibility in the guinea pig.

Materials and Methods

Animals and feeding: Sixty growing male Hartley guinea-pigs (mean body weight 411 g) were housed individually in 150 × 200 mm wire-bottomed cages during feeding trials. The animal room was maintained at a temperature of 22 ± 2°C, with a 12 hr light-dark cycle.

The animals were fed the experimental diet containing one fiber source for at least 6 days before a 5 day digestion trial. Free access was given to the diet and water. Fresh food and water were placed in the cages every day at 10:00–12:00. Coprophagy was not prevented. The feed consumption of each animal was recorded daily. Feces were collected daily and stored in plastic bottles for later analysis after being oven-dried overnight at 60°C.

Diet: The experimental diets consisted of three combinations (3:1, 1:1, 1:3) of the basal diet and four fiber sources, dehydrated alfalfa, oaten hay, commercial cubed alfalfa hay and beet pulp. Consequently, twelve experimental diets were fed, one to each of 12 groups of five animals. Amounts (%) of neutral-detergent fiber (NDF) and acid-detergent fiber (ADF) of fiber sources were 38.3 and 23.1 for alfalfa meal, 32.8 and 16.2 for beet pulp, 37.8 and 29.0 for oaten hay and 39.2 and 30.0 for hay cube, respectively. The composition of the ingredients in the basal diet and the chemical compositions of each of the experimental diet are shown in Tables 1 and 2, respectively. Compositions of dietary fiber components increased as the level of fiber sources increased. On the other hand, dietary crude protein had a tendency to decrease as the level of fiber sources increased.

Analytical methods: The pooled fecal samples from

Table 1. Composition of the basal diet (%)

Ingredients	
Corn	50.00
Wheat	4.07
Wheat flour	22.07
Corn gluten meal	117.70
Salt	0.50
CaCO ₃	2.04
Ca ₃ (PO ₄) ₂	1.32
Vitamin mix ¹	0.50
Choline chloride	0.30
Vitamin C calcium	1.00
Mineral mix ²	0.50

¹Composition (mg/kg mixture): thiamin hydrochloride 600; riboflavin 600; pyridoxine hydrochloride 700; nicotinic acid 3000; D-calcium pantothenate 1600; folic acid 200; biotin 20; cyanocobalamin 1; retinol palmitate 220; DL- α -tocopheryl acetate 5000; cholecalciferol 2.5; menadione 5. The rest is sucrose. ²Composition (% of mixture): CaHPO₄ 50.0; NaCl 7.4; K₃C₆H₅O₇ · H₂O 22.0; K₂SO₄ 5.2; MgO 2.4; MnCO₃ 0.35; Fe-Citrate 0.6; ZnCO₃ 0.16; CuCO₃ 0.03; KIO₃ 0.001; Na₂SeO₃ 0.0007; Cr₂K(SO₄)₂ · 12H₂O 0.055 and sucrose 11.8033.

the digestion trials were ground to under 1 mm and analyzed for dry matter, crude protein [3], neutral detergent fiber (NDF) [27] and acid detergent fiber (ADF) [26]. The experimental diets fed were also analyzed for the same chemical components as the fecal samples.

Statistics: The data were analyzed as a single factorial design and differences were tested for statistical significance by Duncan's multiple range test [9].

Results

Feed intake and body weight gain: Feed intakes and weight gains are shown in Fig. 1. On a metabolic body size (kg^{0.75}) basis, dry matter intake was highest on the diet containing alfalfa meal, followed by hay cubes and oaten hay, and lowest on the diet containing beet pulp. Feed intake of animals fed alfalfa meal, oaten hay and hay cubes increased in response to increases in the proportion of each fiber source in the diet.

The body weight gain had tendency to be greater in all 50% fiber groups than in all 25% fiber groups. On beet pulp, body weight gain was significantly lower in the 25% group than in 50% group. On oaten hay, both

Table 2. Chemical composition of experimental diet (%)

Fiber source	Percent of diet	Moisture	NDF	ADF	Crude protein	Crude ash
Alfalfa meal	25	10.6	17.2	10.0	19.5	6.5
	50	8.9	26.8	16.2	18.6	8.5
	75	8.9	32.4	22.1	17.1	8.5
Beet pulp	25	8.9	16.3	9.3	18.5	6.2
	50	10.0	22.5	12.6	15.0	6.2
	75	11.0	30.6	16.7	12.3	6.4
Oaten hay	25	9.4	15.9	9.4	19.2	6.7
	50	10.5	23.0	15.4	16.4	7.8
	75	9.7	32.1	19.8	14.1	9.0
Hay cube	25	8.4	17.9	11.6	20.4	6.9
	50	11.8	23.9	16.8	18.9	8.2
	75	11.6	32.3	25.7	17.5	9.0

ADF: acid detergent fiber; NDF: neutral detergent fiber.

Fig. 1. Feed intake (g/kg^{0.75}/d), body weight gain (g/5 d), and feed efficiency (%) in the guinea pig given a diet containing different fiber sources in different proportions (n=5). ■: Feed intake; ▨: Body weight gain; ▩: Feed efficiency which is the ratio of weight gain to feed intake. a,b: Mean values with different superscripts among the same concentrations of each fiber source are significantly different (P<0.05). x,y,z: Mean values with different superscripts in each fiber source are significantly different (P<0.05).

feed intake and body weight gain were highest in the 75% fiber group. On alfalfa meal and hay cube, feed intake was highest in the 75% fiber groups, but body weight gain was only similar to or even lower than in the 50% fiber groups.

Feed efficiency: Feed efficiency estimated as the ratio of body weight gain to feed intake during the digestion trial is included in Fig. 1. Feed efficiency was highest on hay cube and lowest on beet pulp in the 25% groups. In the 50% fiber groups, however, feed efficiency was higher on beet pulp than on oaten hay and hay cube. There was no significant difference between all 75% fiber groups.

Apparent digestibility: Apparent digestibilities of dry matter and crude protein are shown in Table 3. The digestibility of dry matter decreased as the proportion of fiber in the diet increased. Dry matter digestibility was highest on the beet pulp diets. There was no difference in apparent digestibility of crude protein among fiber sources in the 25% group, but the digestibility of crude protein was lower on beet pulp than on the other fiber sources in the 50 and 75% groups.

Digestibilities of ADF and NDF (Table 4) were highest on the beet pulp diets. The difference between beet pulp and the other diets was most marked in the 25% fiber groups, and tended to decrease as the proportion of fiber source increased. ADF digestibility was lowered negatively with the proportion of fiber source increased in the beet pulp and oaten hay groups, but not in the alfalfa and hay cube groups. There was no significant difference in NDF digestibility between the

Table 3. Apparent digestibility of dry matter and crude protein in guinea pigs given a diet containing different fiber sources in different proportions (%) (n=5)

Fiber source (%)	Dry matter				Crude protein			
	25	50	75	SEM	25	50	75	SEM
Alfalfa meal	76.6 ^{a,x}	69.9 ^{a,y}	67.0 ^{ab,y}	2.10	73.9 ^x	78.7 ^{b,xy}	82.9 ^{a,y}	1.68
Beet pulp	86.6 ^{b,x}	82.4 ^{b,xy}	72.8 ^{b,y}	3.27	76.9 ^x	66.7 ^{a,xy}	53.4 ^{b,y}	4.91
Oaten hay	79.5 ^{ab,x}	72.6 ^{a,xy}	65.1 ^{a,y}	3.20	76.3	72.5 ^a	63.0 ^c	4.89
Hay cube	80.5 ^{a,x}	71.0 ^{a,y}	66.0 ^{a,y}	2.40	79.7	71.9 ^a	71.0 ^d	2.73
SEM	2.56	2.17	2.07		3.32	3.32	2.66	

^{a,b}: Mean values in the same column with different superscript letters are significantly different (P<0.05).

^{x,y}: Mean values in the same row with different superscript letters are significantly different (P<0.05).

Table 4. Digestibility (%) of ADF and NDF in the guinea pig given a diet containing different fiber sources in different proportions (%) (n=5)

Fiber source (%)	ADF				NDF			
	25	50	75	SEM	25	50	75	SEM
Alfalfa meal	37.8 ^a	33.1 ^a	36.0 ^a	3.61	39.9 ^a	44.1 ^a	44.7 ^a	4.83
Beet pulp	74.4 ^{b,x}	69.8 ^{c,x}	49.7 ^{b,y}	5.91	70.4 ^b	73.5 ^b	60.0 ^b	6.91
Oaten hay	57.0 ^{c,x}	46.3 ^{b,xy}	39.3 ^{ab,y}	4.30	42.8 ^a	41.9 ^a	40.9 ^a	6.18
Hay cube	49.0 ^{c,x}	35.6 ^{ab,y}	43.8 ^{ab,xy}	4.56	48.9 ^a	37.3 ^a	41.9 ^a	5.60
SEM	3.12	4.30	3.81		3.32	3.32	2.66	

ADF: acid detergent fiber; NDF: neutral detergent fiber. ^{a,b}: Mean values in the same column with different superscript letters are significantly different (P<0.05). ^{x,y}: Mean values in the same row with different superscript letters are significantly different (P<0.05).

alfalfa, hay cube and oaten hay groups at all levels of fiber source in the diet.

Discussion

Feed intake increased as the proportion of alfalfa, oaten hay or hay cubes increased in the diet in guinea-pigs. It is generally recognized that nonruminants eat enough feed to satisfy their energy requirement, but it has been reported that feed intakes and average weight gains decreased as the level of dietary alfalfa increased in pigs fed 20, 40 and 60% alfalfa [19]. These suggest that guinea pigs are much more tolerant to the mixing of forage crops in feed than pigs.

Replacement of a diet with 50% finely ground cellulose resulted in no increase in feed intake and no change in body weight, suggesting that guinea pigs can utilize fiber efficiently as an energy source [15]. Nevertheless, body weight gain on the forage-based fiber sources did not increase between 50% and 75% fiber source in the basal diet, despite the linear increase in feed intake.

Although guinea-pigs are more efficient in fiber digestion than many other hindgut fermenters [23, 26], digestibility of fiber is generally lower than that of any of the components of the basal diet, and thus available energy tends to decrease as the proportion of the fiber source increases. Therefore digestible energy intakes were probably similar on the 50% and 75% fiber source diets, despite greater dry matter intakes on the latter.

Beet pulp contains approximately 8% crude protein, 54% NDF and 33% ADF of dry matter [29]. In the rabbit, which digests fiber less efficiently than many other small hindgut fermenters [23], the digestibility of the crude fiber of beet pulp was 70%, suggesting that the fiber in beet pulp is highly digestible [10]. In this experiment, the digestibilities of dry matter and fiber (NDF and ADF) were much higher on beet pulp than on the forage-based fiber sources. Beet pulp may therefore be a useful fiber source for feeding also to guinea pigs.

The guinea-pigs fed the beet pulp diets consumed less dry matter than the animals fed the other fiber

sources at all three levels of inclusion, and gained less weight than others on the 25% and 75% fiber source levels, but the body weight gains of the animals fed on a 50% beet pulp diet were similar to those on the other 50% diets, with the result that feed efficiency was higher than on the other fiber sources. The low feed intakes on beet pulp at the level of 75% than on the other fiber source could limit the use of beet pulp as a ration component for guinea-pig feeding in spite of the highly digestible nature of its fiber components.

Guinea pigs tolerate dilution of the diet with cellulose in their growth [15], but, on the other hand, very low growth rates for guinea pigs fed diets containing no fiber were observed [7]. It can therefore be considered that beet pulp has no stimulating effect as a fiber source on the growth of guinea-pigs on the 25% level.

Higher digestibilities of fiber components in guinea pigs fed beet pulp than in guinea pigs fed the other fiber sources suggests that the addition of beet pulp to the diet stimulates microbial fermentation and production of SCFAs resulting in an increase in microbial proliferation in the cecum. Lower apparent digestibility of crude protein on a beet pulp diet than on the other diets might be caused by an increased amount of fecal excretion of microbial protein.

The SCFAs produced in the cecum are easily absorbed [2, 6, 12, 17, 18 and 30] and utilized as a source of substrate and energy in the epithelial cells of the large intestine [14, 20] and in liver [8, 25]. Therefore, SCFAs are considered to greatly contribute to energy metabolism in guinea pigs fed beet pulp compared with animals fed the other fiber sources. Although SCFAs were investigated intensely as factors limiting food intake [4], many results do not indicate a satiating effect of circulating SCFAs in ruminants [11], but propionate infusions into the portal vein depressed intake whereas those into the jugular vein had no effect in sheep [1]. This still suggests the possibility that SCFAs have a depressing effect on feed intake. Increased production of SCFAs in the cecum may affect feed intake in guinea pigs fed on a beet pulp containing diet.

The difference in crude protein composition between levels of fiber source in the diet were largest in the beet pulp diet. The possibility that the low level of protein in the diet containing 75% beet pulp affected feed intake cannot be neglected, because it has been reported that feed intake decreased as the dietary level of pro-

tein decreased in hamsters [5, 24].

Further investigation is nevertheless needed to clarify the reason why feed intake was depressed by 75% addition of beet pulp, because the control of feed intake is the result of various physiological interactions that are integrated in the overall eating response.

In conclusion, guinea-pigs prefer diets containing forage over those based on the residual fiber source beet pulp, even though the fiber of beet pulp is often more digestible than that of forages. As the guinea pig seems to prefer relatively large amounts of fiber in its diet, the most appropriate combination of forage materials and beet pulp as fiber sources in the diet for optimal levels of feed intake and growth of guinea-pigs requires careful consideration.

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