Effects of a Return Chewing Gum/Packaging Material Mixture on In Situ Disappearance and on Feed Intake, Nutrient Digestibility, and Ruminal Characteristics of Growing Steers[1,2]

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ABSTRACT: In situ and in vivo digestibility experiments were conducted to determine the acceptability, digestibility, and safety of a return chewing gum/packaging (G/P) material mixture when fed to steers. In the in situ experiment, both ruminal and intestinal disappearances were measured. Two ruminally and duodenally cannulated steers, which were given free access to alfalfa hay (AH), were used in this study. Duplicate Dacron bags containing the G/P were incubated in the rumen for 0, 3, 6, 12, 24, and 48 h. After ruminal incubation, the 12-, 24-, and 48-h bags were placed in the duodenum and collected in the feces to determine intestinal disappearance. In situ ruminal DM disappearance was greater than 70% for all substrates tested at 0 h, indicating high solubility of the substrates in water, and began to reach a plateau after 12 h of incubation. Intestinal in situ disappearance was not different ($P > .25$) from zero. In the digestion trial, four ruminally cannulated steers (337 ± 21.3 kg BW; mean ± SD) were used in a 4 × 4 Latin square design with the following treatments: 0) 50% corn (C), 50% AH; 10) 45% C, 45% AH, 10% G/P; 20) 40% C, 40% AH, 20% G/P; 30) 35% C, 35% AH, 30% G/P. Steers fed G/P-containing diets had greater ($P < .01$) DMI than the control steers. Increasing the G/P resulted in a linear ($P < .05$) increase in DMI. Apparent DM digestibility tended to be higher ($P < .10$) for the G/P-containing diets than for the control. A quadratic effect ($P < .05$) on digestible DMI was observed, with greater ($P < .01$) digestible DMI values for G/P-containing diets (4.8 vs 5.8 kg/d). Digestible organic matter and total nonstructural carbohydrate intakes followed trends similar to those of DM. Apparent aluminum digestibility of G/P-containing diets was not different ($P > .13$) from zero. The level of G/P in the diet had no effect ($P > .2$) on total VFA concentration or ruminal pH. There was a linear decrease ($P < .01$) in the molar percentage of isobutyrate and isovalerate in addition to a linear increase ($P < .01$) in butyrate and valerate with increasing levels of G/P. There was a quadratic effect ($P < .01$) on molar proportions of acetate and propionate and on the acetate:propionate ratio. Results of both experiments suggest that G/P may be fed to safely replace up to 30% of corn-alfalfa hay diets for growing steers with advantages in improving DMI and digestibility.

Key Words: Confectionery By-products, Chewing Gum, Steers, Digestion

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Introduction

Confectionery by-products are becoming more available as animal feed ingredients because of the increasing cost of incineration or disposal in landfills. In addition, pressure to minimize the solid waste stream is encouraging the evaluation of alternative uses for confectionery by-products. Return chewing gum that is past the expiration date not only consists of gum but also its packaging material, which cannot easily be separated. The return chewing gum/packaging (**G/P**) material mixture contains approximately 95% DM, 60% sugar and sugar alcohols, 18% NDF, 16% inert gum base, and 2.5% aluminum. The G/P is devoid of crude protein, other minerals, or vitamins (Wrigleys, personal communication, 1998).

Wolf et al. (1996) reported that adding G/P to a corn silage-based growing diet improved body weight gains and feed efficiency ($P < .05$) in feedlot steers. The primary objectives of this study were to determine 1) the ruminal and postruminal in situ disappearance of G/P and 2) whether increasing levels of G/P would affect

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ruminal fermentation and nutrient digestion in alfalfa hay-corn diets for growing steers.

Materials and Methods

In Situ Trial. Extent of in situ DM disappearance was determined on regular and sugarfree gum (Doublemint and Extra, respectively; Wm. Wrigley Jr. Company, Chicago, IL). Substrates were ground to reduce the particle size to approximately 5 mm in length. Five grams of substrate was placed in Dacron bags (approximately 7 × 14 cm) with a pore size ranging from 20 to 70 μm. Bags were numbered individually and tied securely at the top with nylon string, after which the bags were placed in a large-mesh nylon bag that could be closed with a drawstring. Bags that were not ruminally incubated (0 h) were rinsed in a two-cycle washing machine and processed as described below. A 580-g weight placed in the bottom of the large-mesh bag was used to secure the Dacron bags in the ventral sac of the rumen. Bags were incubated for 0, 3, 6, 12, 24, and 48 h in the rumen of two steers (Simmental-cross, 2 yr old) that were given free access to alfalfa hay and water. Steers had ad libitum access to trace mineralized salt blocks (containing 98.0% NaCl, .350% Zn, .280% Mn, .175% Fe, .035% Cu, .007% I, and .007% Co). Two replications (i.e., steers) of each substrate in duplicate were performed. After incubation, all bags were rinsed in a two-cycle washing machine, dried at 57°C for 48 h in a forced-air convection oven, and weighed so that DM disappearance could be calculated.

After ruminal disappearance was calculated, undigested residues contained in the 12-, 24-, and 48-h bags were placed into the proximal duodenal cannula and collected in feces upon excretion. Prior to insertion into the duodenum, bags were sewn shut and weighed. After excretion, bags were washed and dried, and DM disappearance was calculated as above.

Data were analyzed by analysis of variance according to the GLM procedures of SAS (1985). Data were sorted by substrate, and model sums of squares included time and animal nested within time effects.

Digestion Trial. All procedures used in this experiment were approved by the University of Illinois Laboratory Animal Care Committee. Four ruminally cannulated Simmental-cross growing steers (337 ± 21.3 kg BW; mean ± SD) were used in a feed intake and nutrient digestibility experiment consisting of four 14-d periods. Each period had a 10-d adaptation phase and a 4-d collection phase. A 4 × 4 Latin square design was used to allot the steers to four dietary treatments. The four treatments were 0) 50% corn (**C**), 50% alfalfa hay (**AH**); 10) 45% C, 45% AH, 10% G/P; 20) 40% C, 40% AH, 20% G/P; 30) 35% C, 35% AH, 30% G/P. Corn was fed whole, and the hay was chopped to an average particle length of 2 cm. The G/P was ground through a .95-cm screen to an average particle length of .5 cm. Diets were balanced to meet or exceed the nutrient requirements for growing steers (NRC, 1984). During the adaptation phase, steers were given ad libitum access to complete mixed diets, allowing for at least 10% orts. During the collection phase, steers were fed at 90% of their average feed consumption from d 7 to 10. Steers had ad libitum access to trace mineralized salt blocks (as defined earlier) and water.

Steers were individually housed in stanchions in a temperature-controlled (21°C) room with constant fluorescent lighting and fed daily at 0800 and 1700. At the time of feeding, steers were ruminally dosed with 3.0 g of chromic oxide (6.0 g/d). Fecal grab samples were collected twice daily on d 10 to 14, and approximately 100 g of each sample (as-is basis) was composited for each steer. Chromium concentration of fecal material was determined (Williams et al., 1962) so that apparent digestibility could be calculated using Cr as an external marker.

Samples of feed were obtained daily from d 9 to 13. Feed and fecal samples were dried at 57°C, ground in a Wiley mill (2-mm screen), and composited at the end of each period. Feed and fecal samples were analyzed for DM, OM (AOAC, 1975), and aluminum (Slavin et al., 1975). Total nonstructural carbohydrates (**TNC**) were determined with the procedure of Smith (1969), except that ferricyanide was the color indicator.

On d 14 after the morning feeding, ruminal fluid was collected at 2, 4, 6, and 8 h after feeding and strained through eight layers of cheesecloth. The pH was measured, and 50 mL was saved and acidified with 3 mL of 6 *N* HCl, then frozen (–4°C) and subsequently analyzed for VFA concentrations (Erwin et al., 1961).

Data were analyzed as a 4 × 4 Latin square design using the GLM procedures of SAS (1985). Model sums

Table 1. Least squares means for ruminal in situ disappearance of return chewing gum/packaging material substrates

Item	Incubation time, h 0	3	6	12	24	48	SEM
	% Disappearing, DM basis						
DMT[a]	72.1	76.6	78.5	79.6	79.7	79.6	.98
Extra[b]	71.6	74.5	73.7	74.1	71.6	72.2	1.07

[a]DMT = Whole Doublemint gum and packaging material.
[b]Extra = Whole Extra gum and packaging material.

Table 2. Least squares means for intestinal in situ disappearance of return chewing gum/packaging material substrates

Item and incubation time, h[a]	Disappearance, %	SEM
DMT[b]		
12	–.2	3.18
24	–1.8	2.60
48	–4.2	3.18
Extra[c]		
12	–.9	1.28
24	–1.0	1.57
48	–1.5	1.28

[a]Incubation time in the rumen prior to the intestinal incubation.
[b]DMT = Whole Doublemint gum and packaging material.
[c]Extra = Whole Extra gum and packaging material.

of squares for the Latin square design included animal, period, and treatment effects. Treatment effects were tested using the following contrasts: 1) treatment 0 (control) vs 10, 20, and 30 (percentage of G/P in the diets); 2) linear effect of G/P supplementation; and 3) quadratic effect of G/P supplementation. Data collected at various times after feeding (ruminal pH and VFA concentrations) were analyzed as a split plot (Gill and Hafs, 1971). The interaction of treatment, animal, and period was used as the error term to test whole-plot effects (treatment, period, and animal).

Results and Discussion

In Situ Trial. Least squares means for ruminal in situ DM disappearance of G/P-substrates are presented in Table 1. Both regular (Doublemint) and sugarless (Extra) chewing gum/packaging material were readily fermentable. Over 70% of the DM disappeared at time zero, probably resulting from solubilization of the sugar or sorbitol components of the substrates. As incubation time increased, DM disappearance slightly increased, then began to reach a plateau after 12 h of fermentation.

Least squares means for intestinal in situ DM disappearance of G/P-substrates are presented in Table 2. Disappearance of G/P substrates after ruminal fermentation was not different ($P > .25$) from zero, suggesting that all of the digestible components (carbohydrates and polyols) in G/P were degraded and(or) solubilized in the rumen.

Digestion Trial. Ingredient and chemical compositions of diets fed to growing steers are presented in Table 3. The basal diet consisted of an equal mixture of whole shelled corn and alfalfa hay. One percent urea and 5% molasses were added to the whole shelled corn. Urea was added to provide a readily available source of N to the ruminal microbiota in conjunction with the rapidly fermentable sugar in the G/P. Molasses was added to the corn so the urea would not settle out and to control dust.

Dietary OM composition decreased slightly as level of G/P increased in the diet. This may be explained by the fact that the G/P contained a higher percentage of mineral matter (e.g., aluminum) than the basal diet it replaced. Total nonstructural carbohydrates increased with increasing levels of G/P due to the high level of simple carbohydrates (i.e., sugar and sorbitol) in the G/P in comparison to the AH it replaced in the basal diet.

Least squares means for nutrient intakes, apparent nutrient digestibilities, and digestible nutrient intakes are presented in Table 4. Dry matter intakes and digestible DMI were increased ($P < .01$) such that steers fed G/P-containing diets consumed, on average, .9 and 1.1 kg/d more DM and digestible DM, respectively, than steers fed the control diet. The rapid disappearance of the G/P as demonstrated in the in situ experiment may have decreased rumen fill, allowing more feed to be consumed. Conversely, data may suggest that G/P enhanced acceptability of the C-AH diet, resulting in improved intakes. There was also a trend ($P < .10$) for improved DM digestibility of the G/P diets vs the control diet, suggesting the G/P is more digestible than the basal diet it replaced.

Table 3. Ingredient and chemical composition (dry matter basis) of diets fed to ruminally cannulated growing steers

	Treatment, %G/P[b]			
Item	0	10	20	30
Ingredient				
Corn	47.0	42.3	37.6	32.9
Urea	.5	.45	.40	.35
Molasses	2.5	2.25	2.0	1.75
Alfalfa hay[a]	50	45	40	35
G/P	0	10	20	30
Composition				
OM	95.6	95.3	95.0	94.7
TNC[c]	38.5	39.9	41.4	42.8
CP	14.6	13.2	11.8	10.4

[a]Alfalfa hay was ground through a hammermill without a screen.
[b]Ground (.95-cm screen) return chewing gum/packing material mixture.
[c]TNC = total nonstructural carbohydrates.

Table 4. Least squares means for nutrient intake, apparent nutrient digestibility, and digestible nutrient intake of diets containing return chewing gum/packaging (G/P) material fed to ruminally cannulated, growing steers

	Treatment[a]					P[b]		
Item	0	10	20	30	SEM	0 vs G/P	L	Q
Collection period intake, kg/d								
DM	7.1	7.9	8.0	8.0	.21	.01	.02	.08
OM	6.8	7.6	7.6	7.6	.20	.01	.03	.08
TNC[c]	2.7	3.2	3.3	3.4	.07	.01	.01	.07
Apparent digestibility, %								
DM	67.9	74.2	72.4	73.0	2.07	.07	.19	.21
OM	68.3	75.1	73.8	74.7	2.04	.04	.10	.21
TNC	82.7	88.8	94.0	94.5	3.73	.06	.05	.47
Digestible nutrient intake, kg/d								
DM	4.8	5.9	5.8	5.8	.19	.01	.01	.03
OM	4.6	5.7	5.6	5.6	.18	.01	.01	.02
TNC	2.2	2.8	3.1	3.2	.09	.01	.01	.04

[a]Treatment: 0, 10, 20, and 30% G/P on a DM basis.
[b]P-value for 0 vs average of the G/P treatment and linear (L) and quadratic (Q) effects of G/P supplementation.
[c]TNC = total nonstructural carbohydrates.

Organic matter followed trends similar to those of DM (Table 4). There was a linear increase ($P < .05$) in OM intake that resulted in greater ($P < .05$) intakes for the G/P-containing diets than for the control (7.6 vs 6.8 kg/d, respectively). In addition to the improved OM intakes, G/P-containing diets had improved ($P < .05$) apparent OM digestibilities that resulted in 1.0 kg/d more ($P < .01$) digestible OM intake for steers fed the G/P-containing diets. Khalili and Huhtanen (1991) found that sucrose (1 kg/d) had no effect on apparent digestibility of OM when supplementing a grass silage-barley diet.

As would be expected, there was a linear increase ($P < .01$) in TNC intake with increasing levels of G/P because of the higher TNC content (DM basis) of the G/P vs that of the basal diet (52.8 vs 38.5%). Apparent digestibilities of TNC tended ($P < .10$) to be higher for G/P-containing diets vs the control, probably due to the high digestibility of the TNC component of the G/P (mostly sugars), as suggested by the rapid in situ DM disappearance. It should be noted that the TNC content of the basal diet was mostly of corn origin. Corn had 65.0% TNC and alfalfa hay had 12.0% TNC on a DM basis (data not shown). The TNC in corn is mostly starch, and that starch is known for its slower ruminal fermentability compared with the starch in other cereal grain sources such as barley (Waldo, 1973). There was a quadratic effect ($P < .05$) for digestible TNC intake that resulted in greater ($P < .01$) digestible TNC intakes for the G/P-containing diets (2.2 vs 3.0 kg/d).

The least squares means of aluminum intake and apparent aluminum digestibility are presented in Table 5. As would be expected, intake of aluminum increased ($P < .01$) linearly as the level of G/P increased in the diet, resulting in higher ($P < .01$) aluminum intakes for G/P-containing diets than for the control diet. The control diet contained less than 5 ppm aluminum, which was below our detection limits. Consequently, apparent digestibility could not be calculated. Aluminum digestibilities were negative for G/P-containing diets but were not different ($P > .13$) from zero.

Aluminum ingestion may occur from a variety of sources, including soil and water contamination, plant-accumulated aluminum, and as a feed additive (Allen, 1984). In general, ingested aluminum is poorly absorbed but has been shown to alter utilization of phos-

Table 5. Least squares means for aluminum intake and apparent aluminum digestibility of diets containing return chewing gum/packaging material fed to ruminally cannulated, growing steers

	Treatment[a]				
Item	0	10	20	30	SEM
Collection period intake, g/d[b]	—	21.8	44.3	66.3	3.20
Apparent digestibility, %[c]	—	–6.4	–4.9	–6.9	5.04

[a]Treatment: 0, 10, 20, and 30% G/P on a DM basis.
[b]Treatment 0 vs 10, 20, and 30 ($P < .01$); linear effect ($P < .01$).
[c]Least squares means not different from zero ($P > .13$).

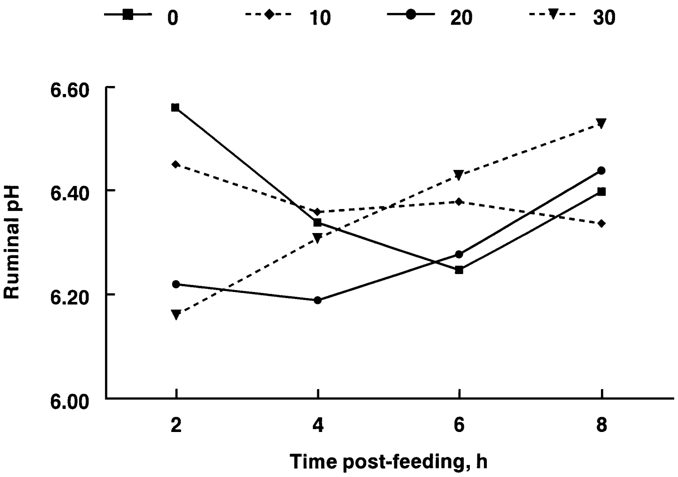

Figure 1. Postfeeding ruminal pH values for steers fed return chewing gum/packaging material at 0, 10, 20, and 30% of dietary DM. SEM = .05.

phorus, fluorine, calcium, and magnesium (Allen, 1984). Valdivia et al. (1978) fed steers aluminum as soluble $AlCl_3$ at levels up to 1,200 ppm for 84 d without any negative effects on feedlot performance. Others (Hobbs et al., 1954) fed .5% aluminum sulfate to steers and 1% aluminum sulfate to lambs (Thompson et al., 1959) and found no depression in animal performance. In the present study, steers were fed up to .8% aluminum (30% G/P treatment), and no negative effects on feed intake, diet digestibility, or ruminal characteristics were detected.

Ruminal pH was decreased (6.56, 6.45, 6.22, and 6.16 for diets containing 0, 10, 20, and 30% G/P, respectively) at 2 h after feeding as the level of G/P increased (Figure 1). This may be due to the rapid fermentability of the sugar in the G/P in comparison to the basal diet it replaced. Similar to the observations of Khalili and Huhtanen (1991), the lowest pH was obtained earlier after feeding the 30% G/P diet (2 h) than after feeding the basal diet (6 h). The highest level of sugar (30% G/P) did not result in acidotic conditions (pH remained above 6.1). Harmon et al. (1985) ruminally dosed 12 g of glucose/kg of BW (compared with ~4.7 g of sugar/kg of BW in steers fed 30% G/P) in order to induce acute acidosis. They measured ruminal pH as low as 4.2. In their study, steers fed the control diet (70% concentrate) experienced a marked decline in ruminal pH to 5.8, which was associated with a decrease in DM intake (13.6 vs 1.6 kg/d).

Averaged over time, pH was not different ($P > .2$) among treatments (Table 6). Amount of G/P in the diet had no effect ($P > .2$) on total VFA concentration (Table 6). There was a quadratic decrease ($P < .05$) of acetate and propionate molar proportions in conjunction with a linear ($P < .01$) increase in molar proportion of butyrate as level of G/P increased. This would be expected because highly fermentable sugars (e.g., sucrose, glucose, and molasses) have been shown to increase butyrate concentration at the expense of acetate (Ørskov and Oltjen, 1967; Huhtanen, 1988; Khalili and Huhtanen, 1991). Linear decreases ($P < .01$) in isobutyrate and isovalerate molar proportions also were noted. Huhtanen (1988) and Khalili and Huhtanen (1991) found a lower molar proportion of isovalerate in ruminal VFA with sugar diets and suggested that this was an indication of improvement in the utilization of dietary N. Moreover, the decrease in molar proportion of branched-chain VFA may be due to supplementation of the protein-containing basal diet with the low protein-containing G/P. There was a linear increase ($P < .01$) in valerate, which also was noted by Ørskov and Oltjen (1967) when they fed sucrose- and glucose-supplemented diets to steers. Furthermore, there was a quadratic effect ($P < .01$) for acetate:propionate ratio.

Table 6. Least squares means for ruminal pH and VFA concentrations and molar proportions for ruminally cannulated growing steers fed diets containing return chewing gum/packaging material

	Treatment[a]					P[b]		
Item	0	10	20	30	SEM	0 vs G/P	L	Q
pH	6.4	6.4	6.3	6.4	.07	.78	.55	.59
VFA, m*M*	95.1	99.3	103.3	94.4	6.16	.24	.94	.32
VFA, mol/100 mol								
Acetate	64.1	63.5	60.8	57.8	.41	.01	.01	.03
Propionate	21.2	17.8	17.3	17.4	.50	.01	.01	.01
Butyrate	10.6	14.9	18.2	21.4	.61	.01	.01	.45
Isobutyrate	1.0	.9	.8	.7	.05	.01	.01	.36
Isovalerate	1.9	1.6	1.2	.8	.10	.01	.01	.83
Valerate	1.1	1.4	1.8	1.9	.10	.01	.01	.38
C2:C3[c]	3.0	3.6	3.6	3.4	.09	.01	.04	.01

[a]Treatment: 0, 10, 20, and 30% G/P on a DM basis.
[b]*P*-value for 0 vs average of G/P treatments and linear (L) and quadratic (Q) effects of G/P supplementation.
[c]C2:C3 = Acetate:propionate ratio.

Implications

The use of by-products in animal agriculture is of practical importance. Indeed, a returned chewing gum/packaging material mixture can replace at least 30% of a growing steer's diet (corn and alfalfa hay) without affecting diet safety or acceptability. In addition, intakes may be improved, and steers consuming diets containing returned chewing gum/packaging material could have higher digestible dry matter and organic matter intakes. Use of returned chewing gum/packaging material mixtures in growing feedlot steer diets could maintain production and remove environmental concerns of incinerating or landfilling this by-product.

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