Supplementation with gum arabic fiber increases fecal nitrogen excretion and lowers serum urea nitrogen concentration in chronic renal failure patients consuming a low-protein diet\(^1\)\(^-\)\(^4\)

Donna Zimmaro Bliss, T Peter Stein, Charles R Schleifer, and R Gregg Settle

**ABSTRACT** In chronic renal failure (CRF), plasma concentrations of the products of protein metabolism are increased. Current dietary management is to prescribe a decrease in protein intake. The use of dietary fiber to increase fecal excretion of retained metabolites in CRF may be a beneficial adjunct to a low-protein diet (LPD). Colonic bacteria ferment dietary fiber, providing them with energy for growth and nitrogen incorporation, in turn, increasing nitrogen excretion in feces. Sixteen CRF patients consuming an LPD were randomly assigned to receive a supplement of a highly fermentable fiber, gum arabic (50 g/d), or a placebo (1 g pectin/d) in a prospective, single-blind, crossover design. Fecal bacterial mass and fecal nitrogen content were significantly increased during supplementation with gum arabic compared with the baseline LPD or supplementation with pectin. Serum urea nitrogen was significantly decreased during supplementation with gum arabic compared with the baseline LPD or supplementation with pectin. Nitrogen balance did not change significantly. *Am J Clin Nutr* 1996;63:392–8.

**KEY WORDS** Gum arabic, fiber, chronic renal failure treatment, dietary therapy

**INTRODUCTION**

In chronic renal failure (CRF), plasma concentrations of the products of protein metabolism, including urea, are increased. Retention of these nitrogen metabolites is associated with adverse clinical symptoms such as nausea, vomiting, anorexia, fatigue, lethargy, pruritus, and tremors (1–4). Interventions that restrict protein intake (i.e., low-protein diets [LPDs]) lower the serum urea nitrogen concentration, alleviate adverse clinical symptoms (1, 2, 4), and may slow the progression of CRF (5–9). Although most dietary attempts to treat CRF and to lower serum urea nitrogen involve reducing nitrogen intake, another approach would be to increase nitrogen excretion via feces. Increased fecal nitrogen excretion, from the ingestion of dietary fiber, has been reported in animals, in normal human subjects, and in patients with cirrhosis (10–12). Colonic bacteria ferment dietary fiber, providing them with energy for growth and nitrogen incorporation and, in turn, increasing fecal bacterial mass and nitrogen excretion (11, 13).

There is preliminary evidence that dietary fiber can increase fecal nitrogen excretion and lower serum concentrations of urea and other retained metabolites in CRF patients (14–18). The use of dietary fiber to increase fecal excretion of retained metabolites in CRF may be a beneficial adjunctive therapy. The purpose of this study was to determine whether supplementing an LPD with a highly fermentable fiber, gum arabic (19), would increase fecal nitrogen excretion and fecal bacterial mass and result in lower serum urea nitrogen concentrations.

**SUBJECTS AND METHODS**

**Subjects**

The study sample consisted of 20 adult volunteers (13 males and 7 females) with CRF who had been treated with an LPD for \(\geq\) 4 mo. Sixteen subjects (10 males and 6 females) completed the study protocol. Subjects were excluded from participating if they had a history of liver disease, were on dialysis, had undergone renal transplantation, were pregnant or lactating, or had active gastrointestinal bleeding. The participation of three subjects was discontinued for the following reasons: stroke and...
congestive heart failure in one patient, viral pneumonia and hemodialysis for pulmonary edema in one patient, and accelerated renal failure with pulmonary edema in one patient who died within the following 2 wk. A fourth patient withdrew from the study of his own accord because of difficulty collecting the required specimens. The 16 subjects who completed the study ranged in age from 20 to 72 y. Etiologies of CRF included arteriolar nephrosclerosis (four subjects), diabetic nephropathy (four subjects), glomerulonephritis (three subjects), amyloid nephropathy (one subject), focal glomerulosclerosis (one subject), obstructive uropathy (one subject), polycystic kidney disease (one subject), and scleroderma (one subject). The subjects' mean (± SEM) serum urea nitrogen concentration at baseline was 18 ± 2 mmol/L (50 ± 6 mg/dL) and serum creatinine was 0.39 ± 0.07 mol/L (4.4 ± 0.8 mg/dL). None of the subjects reported uremic symptoms before or during the study. The study and its consent form were approved by the Committee for the Use of Human Subjects in Research at the University of Pennsylvania and Lankenau Hospital, Philadelphia.

Procedures

A randomized, controlled, single-blind clinical trial with a crossover design was used. Baseline data of the subjects' dietary intake, urine and stool outputs (for nitrogen balance), and serum urea nitrogen concentration were obtained over a 5-d period before the fiber protocol was started. Subjects recorded and reviewed their dietary intake with the investigator (DZB) daily. They collected 24-h urine specimens and all their stools daily for 5 consecutive days. Stools were collected in a plastic bag fitted over a toilet seat (Girard Paper Products, Philadelphia) and subsequently placed in a self-sealing plastic freezer bag (Glad-Lock; First Brands Corp, Danbury, CT), which was frozen immediately in dry ice (20). Urine and stool collections were picked up by the investigator daily. Urine volume was measured and aliquots were frozen at −20 °C until analyzed. Stools were weighed and stored at −70 °C until analyzed. Two 10-mL blood samples were drawn on 2 different days between days 1 and 5 of the baseline data collection period, usually on days 2 and 4. Blood specimens were obtained 4–6 h after the afternoon meal was completed and before the evening meal was eaten. Serum was separated by centrifugation at 4 °C for 10 min at 1940 × g and frozen at −20 °C until analyzed.

Subjects were divided randomly into two groups during dietary period 1. The investigator provided subjects in both groups with the juice mixtures and the subjects were not informed of their content. Group A supplemented their usual LPD with 25 g gum arabic (TIC Gums Inc, Belcamp, MD) in 150 mL juice twice daily (ie, 50 g gum arabic/d) for 4 wk. Gum arabic, an extract from the Acacia senegal plant, is a heteropolysaccharide composed of β-galactopyranose, β-glucuronic acid, 4-O-methylglucuronic acid, L-arabinose, and L-rhamnose (21). Gum arabic is generally recognized as safe by the US Food and Drug Administration and is used widely in the production of foods such as puddings and fillings, artificially whipped cream, frostings, candy, chewing gum, beverages including instant coffee and tea, and breakfast cereals (21).

The fiber supplement was ingested with the morning and evening meals. A variety of juices were used, including cranberry, cranberry apple, grape, apple-grape, Harvest blend, and cranraspberry (Welch's Foods Inc, Westfield, NY) depending on the subjects' taste preferences. Fifty grams of gum arabic was provided to approximately double the 40–60 g fermentable substrate (ie, fiber and nonstarch polysaccharides) normally available to colonic bacteria daily. The amount of fermentable substrate normally available was calculated from analyses of intakes with typical Western diets, ideal effluent, and the amount of microbial matter excreted in feces (22–26).

During dietary period 1, group B supplemented their usual LPD with a placebo mixture of 0.5 g pectin (Sigma Chemical Co, St Louis) in 150 mL juice twice daily for 4 wk. The placebo mixture was similar in appearance, taste, and viscosity to the gum arabic mixture. Although pectin is a fermentable fiber, the amount of pectin ingested in the placebo mixture, 1 g/d, was negligible compared with either the 50 g gum arabic/d provided or the amount of dietary fermentable fiber normally presented to the colon. Because the first two subjects commented that the juice and fiber mixtures were "a little thick," 65 mL water was added to each 150-mL sample of juice containing the gum arabic or pectin supplements for subsequent subjects. Subjects were questioned about their tolerance of the fiber supplements on a weekly basis when the supplements were delivered.

During dietary period 2, the gum arabic and placebo treatments were reversed for groups A and B. Group A supplemented their usual LPD with a mixture of 0.5 g pectin in 150 mL juice (plus 65 mL water) twice daily for 4 wk. Group B supplemented their usual LPD with 25 g gum arabic in 150 mL juice (plus 65 mL water) twice daily for 4 wk. Dietary intake was recorded and 24-h urine samples and stool samples were collected during the last 5 d of dietary periods 1 and 2, as described previously. Two 10-mL blood samples were obtained on 2 different days between days 23 and 28 of dietary periods 1 and 2, usually on days 25 and 27, as described previously.

The nutritional status of the subjects was assessed during the baseline period and the two fiber-supplementation periods by measuring their weight, height, triceps skinfold thickness, midarm muscle circumference, and nitrogen balance (27, 28). Serum creatinine was measured from blood drawn during the baseline and fiber-supplementation periods to approximate the subjects' renal function.

Measures

Stool fractionation

Stool samples from each 5-d collection period were pooled for analysis and separated into fractions according to the method of Stephen and Cummings (29). Briefly, feces were lyophilized to a constant weight, mixed with a detergent, and then subjected to a series of rinses, filtrations, and ultracentrifugations. The procedure included the following modifications: fraction B was obtained by pouring the filtrate through a 100-μm nylon mesh filter rather than by aspirating the filtrate, and pellets obtained from the final ultracentrifugation were lyophilized instead of desiccated (personal communication, A Stephen, 1990). The weight of the water-soluble fraction of stool (fraction S) was calculated as the difference between the weight of total stool solids and the weight of fractions A, B, and C (12, 30). The nitrogen content of fraction B was mea-
sured to provide a more accurate calculation of the nitrogen content of the water-soluble fraction.

Prior microscopic and chemical analyses of the stool fractions revealed that fraction A contained undigested fiber, fraction B contained fragments of plant material and few bacteria, and fraction C contained fecal bacteria. Fecal bacterial mass was determined by weighing fraction C (29). Fraction S contained peptides, amino acids, urea, ammonia, minerals, electrolytes, salts, lipids, mucus, and bile acids [A Stephen, personal communication, 1991; (31)].

Nitrogen analyses

The nitrogen contents of total stool solids and of stool fractions A, B, and C were determined by the Kjeldahl method. The nitrogen content of fraction S was calculated as the difference between total fecal nitrogen content and nitrogen contents of fractions A, B, and C. The average weight and nitrogen contents of total stool solids and of stool fractions were calculated for each period of the study. To determine the number of days over which the stool variables in a given period should be averaged, subjects were asked to record the day and time of their last stool before the day of specimen collection for each period. The number of days used in averaging stool variables in a given period was calculated as the difference between the day of the last stool before the specimen collection period began and the day after the specimen collection period ended.

The nitrogen content of urine was determined for each complete 24-h urine collection by the Kjeldahl method. The average daily urine nitrogen content for each subject was calculated by dividing the total urine nitrogen content by the number of days of complete urine collection for each study period.

Serum urea nitrogen concentration was measured with a standard colorimetric method (#640A, Sigma Chemical Co). Serum urea nitrogen results from the two different times that blood was drawn were averaged for data analysis. Serum creatinine was measured with a standard colorimetric method (#555A, Sigma Chemical Co). Serum creatinine results from the two times that blood was drawn were averaged for data analysis.

Nitrogen balance for the baseline period, dietary period 1, and dietary period 2 was calculated by the following equation (32):

\[
N \text{ balance} = N \text{ intake} - (N \text{ output} + \text{the change in the urea N pool}) \text{ (J)}
\]

Nitrogen intake was calculated from the subjects’ protein intake as reported on their daily diet record by using the NUTRITIONIST III computer program (N2 Computing, Silverton, OR) and dividing the values by 6.25. Because gum arabic contains 0.35% nitrogen, 0.175 g nitrogen/d (0.35% \times 50 g gum arabic/d provided in the study) was added to the subjects’ daily nitrogen intake when nitrogen balance was calculated for the period of supplementation with gum arabic (33). The contribution from the 1 g pectin/d provided in the study to nitrogen intake was considered negligible. Nitrogen output was calculated by adding the nitrogen content of total fecal solids to total urinary nitrogen plus 4.28 mg N \cdot kg body wt \cdot d^{-1} for unmeasured losses (eg, skin) (34, 35). The average daily change in the urea nitrogen pool was calculated as the change in serum urea nitrogen multiplied by 60% of body weight, which is equivalent to the urea distribution space in body water (32, 36, 37). This value was then divided by the average of the number of days between the time that blood was drawn and at the end of the dietary period to calculate the average daily change in the urea nitrogen pool. Nitrogen balance during the baseline LPD was not corrected for change in the urea nitrogen pool because serum urea nitrogen was not measured before the baseline period. Thus, the value assumes a zero change in the urea nitrogen pool during the baseline LPD. For data reported on a per kilogram body weight basis, the weight of the subject during the baseline period was used because the subjects’ body weights did not change significantly (no subject gained or lost > 5 kg during the study).

Statistical analysis

A one-way repeated-measures analysis of variance (ANOVA) was used to analyze changes in stool weight and fecal bacterial mass, nitrogen content (of total stool solids, stool fractions, urine, and serum urea nitrogen), serum creatinine, dietary intake (of protein, phosphorus, nonprotein energy, and fiber), nitrogen balance, and other measures of nutritional status among the baseline, pectin, and gum arabic periods. Pair-wise contrasts were used for post hoc comparisons when there was a significant main effect. Statistical analyses were performed using BMDP PC90 statistical software (BMDP Statistical Software Inc, Los Angeles). P values < 0.05 were considered significant.

RESULTS

Effect of gum arabic on stool weight and fecal bacterial mass

The mean wet weight and dry weight (total solids) of stool were significantly greater during the gum arabic period than during the baseline or pectin periods (Figure 1). There was no significant difference between the mean wet weight and dry weight of stool during the baseline and pectin periods. The mean weights of fractions A (undigested fiber), fraction C (fecal

![FIGURE 1. Stool weights of chronic renal failure patients consuming a low-protein diet (LPD) alone and supplemented with pectin or gum arabic. The wet weight of stool and weight of stool solids were significantly greater during the LPD supplemented with gum arabic than during the LPD alone or supplemented with pectin. \( \bar{x} \pm SE; n = 16; \text{ F(2, 30)} = 8.43, P < 0.01; \text{ F(2, 30)} = 21.7, P < 0.0001. \)](https://academic.oup.com/ajcn/article-abstract/63/3/392/4651416/FIGURE1.png)
bacterial mass), and fraction S (water-soluble substances) were significantly greater during the gum arabic period than during the baseline or pectin periods (Figure 2). The mean fecal bacterial mass was ~1.5 times greater during the gum arabic period than during the baseline or pectin periods. There was no significant difference between the weights of fractions A, C, and S during the baseline and pectin periods. There was no significant difference in the mean weight of fraction B (plant fragments and few bacteria) among the baseline, pectin, and gum arabic periods (Figure 2). Fraction C contained the greatest percentage (49%) of the total stool solids on average over the three periods of stool collection. Fractions A, B, and S contained an average of 8%, 5%, and 38% of the total stool solids, respectively.

**Effect of gum arabic on nitrogen excretion and serum urea nitrogen**

The mean nitrogen content of total stool solids (daily fecal nitrogen) was significantly greater during the gum arabic period than during the baseline or pectin period (Figure 3). The mean nitrogen contents of fractions C and S were significantly greater during the gum arabic period than during the baseline or pectin period (Figure 4). The mean nitrogen content of the fraction containing fecal bacteria (fraction C) during the gum arabic period was 1.7 times greater than during the baseline or pectin period and accounted for 59% of the total increase in stool nitrogen content. There was no significant difference in the mean nitrogen content of total stool solids or fractions C and S between the baseline and pectin periods. The mean nitrogen contents of the total stool solids and of fractions C and S during the pectin period were similar to those at baseline.

There were no significant differences in the mean nitrogen contents of fractions A and B among the baseline, pectin, and gum arabic periods (Figure 4). However, fractions A and B showed the same trend toward greater nitrogen content during the gum arabic period than during the baseline or pectin period that was found for total stool solids and fractions C and S. There was no significant difference in urinary nitrogen content among the baseline, pectin, and gum arabic periods (bar ± SEM: 95 ± 7, 89 ± 4, and 84 ± 8 mg N kg⁻¹ d⁻¹, respectively) ($F_{[2,30]} = 1.7, P = 0.21$).

The mean (±SEM) serum urea nitrogen concentration was significantly lower during the gum arabic period (16 ± 2 mmol/L, or 44 ± 5 mg/dL) than during the baseline (18 ± 2 mmol/L, or 50 ± 6 mg/dL) or pectin period (19 ± 3 mmol/L, or 52 ± 8 mg/dL) ($F_{[2,30]} = 4.3, P < 0.05$). There was no significant difference in the mean serum urea nitrogen concentration during the baseline and pectin periods. There was no significant difference in the mean (±SEM) serum creatinine concentration among the baseline (0.39 ± 0.07 mmol/L, or 4.4 ± 0.8 mg/dL), pectin (0.42 ± 0.08 mmol/L, or 4.7 ± 0.9 mg/dL), and gum arabic periods (0.40 ± 0.07 mmol/L, or 4.5 ± 0.8 mg/dL) ($F_{[2,30]} = 2.3, P = 0.12$).

**FIGURE 2.** Fractional stool weights of chronic renal failure patients consuming a low-protein diet (LPD) alone and supplemented with pectin or gum arabic. The weights of stool fractions C, S, and A were significantly greater during the LPD supplemented with gum arabic than during the LPD alone or supplemented with pectin. The weight of fraction C (bacterial fraction) increased the most among the stool fractions. $\bar{x} \pm$ SEM; $n = 16$. $F_{[2,30]} = 10.6, P = 0.01; \; ^* F_{[2,30]} = 22.9, P < 0.0001; \; ^{**} F_{[2,30]} = 21.7, P < 0.05$.

**FIGURE 3.** Total stool nitrogen excretion in chronic renal failure patients consuming a low-protein diet (LPD) alone and supplemented with pectin or gum arabic. Nitrogen content of total stool solids was significantly greater during the LPD supplemented with gum arabic than during the LPD alone or supplemented with pectin. $\bar{x} \pm$ SEM; $n = 16$. $F_{[2,30]} = 36.1, P < 0.0001$.

**FIGURE 4.** Nitrogen content of stool fractions of chronic renal failure patients consuming a low-protein diet (LPD) alone and supplemented with pectin or gum arabic. Nitrogen contents of stool fractions C and S were significantly greater during the LPD supplemented with gum arabic than during the LPD alone or supplemented with pectin. The nitrogen content of fraction C (bacterial fraction) increased the most among the stool fractions. $\bar{x} \pm$ SEM; $n = 16$. $F_{[2,30]} = 18.9, P = 0.0001; \; ^{**} F_{[2,30]} = 45.3, P < 0.0001$. 
Dietary intake and nutritional assessment

Table 1 shows the average protein, phosphorus, nonprotein energy, and dietary fiber intakes (exclusive of the fiber supplements provided by the study) of the 16 subjects during the baseline, pectin, and gum arabic periods. There was no significant difference in any of the above dietary variables among the baseline, pectin, and gum arabic periods. The subjects' protein intake averaged 0.7 g · kg\(^{-1} \cdot d^{-1}\) for the study periods and their dietary fiber intake averaged 0.14 g · kg\(^{-1} \cdot d^{-1}\) (≈11 g fiber/d). There were no significant differences in mean body weight, percentage of ideal body weight, triceps skinfold thickness, midarm muscle circumference, or nitrogen balance among the baseline, pectin, and gum arabic periods.

Gum arabic side effects

Overall, the fiber supplements were well tolerated by the subjects. No subject withdrew from the study because of intolerance to the fiber supplements. There was no significant difference in mean (± SEM) daily stool frequency among the baseline (1.3 ± 0.2 stools/d), pectin (1.2 ± 0.3 stools/d), and gum arabic periods (1.4 ± 0.2 stools/d) as determined by a one-way repeated-measures ANOVA (\(F_{12,30} = 0.8, P = 0.48\)). Eight of the 16 subjects experienced flatulence while ingesting the gum arabic supplement. Typically, the flatulence occurred during the first 2 wk of the gum arabic period and then subsided. In two subjects who weighed ≤ 58 kg, however, flatulence continued for the 4 wk of the supplement period. An independent \(t\) test indicated that subjects who had flatulence during the gum arabic period had a significantly greater total fiber intake (dietary fiber plus gum arabic supplement) per kilogram body weight (\(x ± SEM: 0.89 ± 0.04 g · kg^{-1} · d^{-1}\)) than did the subjects who did not have flatulence (\(0.71 ± 0.04 g · kg^{-1} · d^{-1}\)) (\(t_{11,14} = -2.21, P = 0.04\)).

DISCUSSION

The CRF patients in our study had significantly lower serum urea nitrogen concentrations after ingesting an LPD supplemented with gum arabic than during ingestion of their LPD alone or supplemented with the pectin placebo. On average, the serum urea nitrogen concentration of the subjects was ≥ 12% lower after only 4 wk of supplementation with gum arabic. The subjects concurrently had a significantly greater fecal nitrogen content after 4 wk of supplementation with gum arabic. Total fecal nitrogen content was 41% higher during the gum arabic supplementation period than during the baseline LPD or pectin supplementation period. This is the first study to show that a statistically significant decrease in serum urea nitrogen concentration resulted during a statistically significant increase in fecal nitrogen excretion in CRF patients. This finding supports the hypothesis that supplementing an LPD with a highly fermentable fiber, gum arabic, increases nitrogen excretion in feces, providing an additional approach to lowering serum urea nitrogen.

In addition, this study is the first to show that the bacterial fraction of feces accounted for the majority (59%) of the increase in total stool dry weight and total fecal nitrogen content in CRF patients. These results suggest that colonic bacteria are largely responsible for the decrease in serum urea nitrogen. Colonic bacteria are capable of degrading urea to ammonia (38–41) and of utilizing it for protein anabolism (39, 42, 43). Fermentable fiber, such as gum arabic, provides an energy substrate for bacterial nitrogen incorporation and growth (11, 13).

An alternative mechanism of the action of dietary fiber in CRF was proposed by Yatzidis et al (16). They concluded that locust bean gum adsorbed or sequestered metabolic wastes in the intestinal fluid of CRF patients and thus served as a vehicle for the elimination of these substances in feces. This is unlikely to be the explanation for the decrease in serum urea nitrogen in this study because fraction A, which contained undigested fiber, showed a very small increase in nitrogen content (absolutely and relatively) that did not even approach statistical significance (\(P = 0.30\)). It is unlikely that an adsorbent property of locust bean gum was responsible for the decrease Yatzidis et al (15, 16) observed in their patients' serum urea nitrogen concentrations. Little and Trafford (44) were unable to show the adsorbent properties of locust bean gum in a filtration experiment similar to that reported by Yatzidis et al (15). Tomlin (45) reported that locust bean gum was extensively

| TABLE 1
Dietary intake and assessment of nutritional status of chronic renal failure patients consuming a low-protein diet alone (baseline) or supplemented with pectin or gum arabic

<table>
<thead>
<tr>
<th>Dietary intake</th>
<th>Baseline</th>
<th>Pectin</th>
<th>Gum arabic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (g · kg(^{-1} \cdot d^{-1}))</td>
<td>0.76 ± 0.05</td>
<td>0.72 ± 0.05</td>
<td>0.68 ± 0.04</td>
</tr>
<tr>
<td>Phosphorus (mg · kg(^{-1} \cdot d^{-1}))</td>
<td>10.5 ± 0.7</td>
<td>9.7 ± 0.9</td>
<td>9.8 ± 0.6</td>
</tr>
<tr>
<td>Nonprotein energy (kJ/d)</td>
<td>0.005 ± 0.0005</td>
<td>0.005 ± 0.0005</td>
<td>0.005 ± 0.0005</td>
</tr>
<tr>
<td>Dietary fiber (g · kg(^{-1} \cdot d^{-1}))</td>
<td>0.14 ± 0.01</td>
<td>0.14 ± 0.02</td>
<td>0.14 ± 0.02</td>
</tr>
<tr>
<td>Nutritional status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>79 ± 4</td>
<td>79 ± 4</td>
<td>79 ± 4</td>
</tr>
<tr>
<td>Percentage IBW (%) (^2)</td>
<td>118 ± 5</td>
<td>118 ± 5</td>
<td>118 ± 5</td>
</tr>
<tr>
<td>Nitrogen balance (mg · kg(^{-1} \cdot d^{-1}))</td>
<td>6.4 ± 6.2</td>
<td>6.0 ± 8.5</td>
<td>-0.6 ± 6.9</td>
</tr>
<tr>
<td>TSF thickness (mm) (^3)</td>
<td>13 ± 1</td>
<td>13 ± 1</td>
<td>13 ± 1</td>
</tr>
<tr>
<td>MAMC (cm) (^4)</td>
<td>27 ± 1</td>
<td>27 ± 1</td>
<td>28 ± 1</td>
</tr>
</tbody>
</table>

\(^2\) ± SEM; \(n = 16, P > 0.05\) for all values.

\(^3\) Ideal body weight.

\(^3\) Triceps skinfold thickness.

\(^4\) Midarm muscle circumference.
fermented by fecal bacteria; therefore, locust bean gum may not have met one of the criteria of an effective oral sorbent, which is passage through the intestinal tract unchanged (46). Yatzidis et al (16) did not consider the possibility that changes in the patients' serum urea nitrogen concentrations may have been partly influenced by changes in colonic bacterial protein metabolism stimulated by bacterial fermentation of locust bean gum.

The ≥12% decrease in serum urea nitrogen during the gum arabic supplementation period is consistent with previous observations of a decrease in serum urea nitrogen in CRF patients consuming a fiber-supplemented LPD (16–18). Although some investigators consider urea to be a minor uremic toxin or merely a marker of adequate dialysis (47–49), there is evidence that urea contributes to the symptomatology of CRF. Elevated serum urea nitrogen concentrations have been clearly associated with adverse clinical symptoms that reduce the quality of life, necessitate dialysis, and contribute to morbidity (1–4, 50–52), although the mechanism underlying these effects still requires clarification. Bergstrom and Furst (47) published a thorough review of studies testing the various hypotheses about the toxicity of urea in CRF; these hypotheses include enzyme inhibition (53, 54) and the carbamylation of proteins (analogous to protein glycosylation in diabetes), which has the potential of interfering with normal protein and enzyme functions (55, 56). Whether retained urea and other nitrogenous metabolites hasten the progression of CRF is debatable (57, 58); clarification of this theory has been complicated by the lack of a measure of the glomerular filtration rate that is both precise and practical (59). In our study, the subjects' renal function, estimated by serum creatinine concentration, remained stable. Given the relatively short period of gum arabic supplementation, no change in renal function was anticipated.

There is little information on the amount of dietary fiber ingested by CRF patients consuming an LPD. Analysis of the dietary intake of CRF patients participating in this study revealed that they ingested an average of 11 g dietary fiber/d in their LPDs, which is at the low end of a typical Western diet (22, 24, 60). The additional 50 g gum arabic/d provided in this study increased the subjects' total fiber intake to 61 g fiber/d. Gum arabic was more easily prepared, ingested with greater palatability, and had fewer side effects than did the fibers used by others (14, 16–18). Overall, the gum arabic supplement was well tolerated by the subjects. One of the side effects of locust bean gum ingestion was two to three soft, voluminous stools per day that had an "unusual, intensely bad smell"; another disadvantage was the low palatability of its mixture with cot tonsed oil (16). Little and Trafford (18) reported that four patients were unable to ingest ispaghula because they found it "unpalatable, felt unwell or had diarrhea." Gum arabic had no significant effect on stool frequency. Although 8 of the 16 subjects in this study reported flatulence, no subject withdrew from the study. Our finding that the subjects who(45,134),(974,608) reported flatulence had a greater total fiber intake during the gum arabic supplementation period compared with the subjects who did not have flatulence suggests that gradually increasing the dose of gum arabic to the desired amount over a period of 1–2 wk may decrease flatulence by allowing adaptation. Tuluang et al (61) reported that in rats ∼2 wk of adaptation to a gum arabic supplement was necessary for complete microbial fermentation of gum arabic, measured by the cecal concentration of its byproducts, short-chain fatty acids.

The greater fecal nitrogen excretion during the gum arabic supplementation period had no adverse effects on the nutritional status of the subjects. The subjects' weights remained stable throughout the study. Nitrogen balance did not differ significantly among the study periods. Triceps-skinfold-thickness and midarm-muscle-circumference measurements indicated that the subjects had a moderate depletion of fat and somatic protein stores during all three study periods (28).

In conclusion, CRF patients consuming an LPD supplemented with 50 g gum arabic/d had greater fecal bacterial masses, greater fecal nitrogen excretion, and lower serum urea nitrogen than they did when consuming the LPD alone or supplemented with 1 g pectin/d. Because elevated concentrations of serum urea nitrogen have been associated with adverse clinical symptoms of CRF, the results suggest that gum arabic may be a useful adjunct to an LPD for increasing excretion of nitrogenous wastes in feces. The results encourage further investigation of whether supplementation with dietary fiber may be beneficial in delaying or treating the symptoms of CRF without adversely affecting nutritional status or in permitting greater protein intake for CRF patients without being detrimental to renal function.

We acknowledge RH Rolandelli for his seminal ideas regarding the research hypothesis and A Wasserstein and the physicians and staff of the Renal and Electrolyte Department of the Hospital of the University of Pennsylvania for providing access to their CRF patients. DZB acknowledges the review and contributions of the other members of her dissertation committee: FS Downs and JL Rombeau. We also acknowledge J Berman, M Brody, K Makaroff, and JJ Rajter for their laboratory technical support and thank the patients who volunteered to be subjects in this study.

REFERENCES