Effects of Dietary Fiber on Nutritional Status of Weanling Mice[1]

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ABSTRACT

A 28-day study was conducted to examine interactions between dietary fiber and nutritional status of Swiss White weanling mice. Nine groups of eight mice each were fed semipurified casein-based rations altered by additions of hemicellulose, cellulose, or lignin at levels of 5, 10, or 20% of the ration by weight. Rations did not vary in protein, fat, vitamin, or mineral content but did vary in energy concentration. Weight gain, protein efficiency ratio, feed efficiency ratio, nitrogen balance, fecal fat, fecal dry matter, and total carcass composition were measured. The responses to variable dietary levels of hemicellulose, cellulose, and lignin were not identical. In general, as level of fiber increased, feed consumption decreased, as did weight gain, feed efficiency, protein efficiency, nitrogen balance, apparent digestibilities of protein and fat, percent of fat in feces and percent carcass fat. Total fecal fat, fecal nitrogen, and total fecal dry weight tended to increase with increased levels of fiber in the rations. Mice fed the 10% hemicellulose rations exhibited the best overall performance. Liver abnormalities were noted in mice fed lignin but not in mice fed cellulose or hemicellulose.

Interest in the effect of dietary fiber on the nutritional status of humans has grown in recent years. Researchers have noted a decrease in dietary fiber in diets of industrilized western populations (Robertson 1972). With this decrease there has been an increased prevalence of such diseases as diabetes mellitus, coronary heart disease (Trowell 1973), diverticular disease of the colon, gall bladder disease, varicose veins, hiatus hernia (Burkitt 1975, Burkitt et al 1974, Findlay et al 1974, Painter and Burkitt 1971), and tumors of the colon (Painter and Burkitt 1971), compared with population groups with higher fiber consumption and different dietary habits.

An increase in the fiber content in human diets is being encouraged and advocated. Lay publications and commercial advertising imply that high fiber diets will cure a wide variety of human ills, but many questions regarding the effect of high fiber consumption on the nutritional status of humans are unanswered.

Much has been reported about the effect of dietary fiber on ruminant and nonruminant animals in regard to the economics of domestic animal production in agriculture (Lyford et al 1956, Meyer 1956, Omar et al 1971). Our study investigated concerns related to human nutrition as it might be affected by increased dietary fiber consumption, specifically, the influence of graded levels of cellulose, hemicellulose, and lignin.

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TABLE I
Composition of Rations With Different Kinds and Levels of Fiber

Ingredients (g/100 g of Ration)	Cellulose			Hemicellulose			Lignin		
	5%	10%	20%	5%	10%	20%	5%	10%	20%
Fiber	5	10	20	5	10	20	5	10	20
Vitamin mix[a]	2	2	2	2	2	2	2	2	2
Mineral mix[b]	5	5	5	5	5	5	5	5	5
Corn oil[c]	10	10	10	10	10	10	10	10	10
Sucrose[d]	8	8	8	8	8	8	8	8	8
Wheat starch[e]	60	55	45	60	55	45	60	55	45
Casein	10	10	10	10	10	10	10	10	10
Total kilocalories (per 100 g of ration)	402	382	342	402	382	342	402	382	342
Crude protein[f]	10	10	10	10	10	10	10	10	10

[a]Vitamin ration fortification mixture (ICN Nutritional Biochemicals Corporation, Cleveland, OH).
[b]Hegsted salt mixture (ICN Nutritional Biochemicals Corporation).
[c]Mazola, Best Foods, CPC International Inc., Englewood Cliffs, NJ.
[d]Regular sugar.
[e]Varying amounts added to make 100 g of ration.
[f]Conversion factor 6.25.

TABLE II
Influence of Dietary Fiber on Feed and Energy Consumption and Weight Gain in Mice

Ration Composition	Mean Values for 28-Day Feeding Trial[a]		
	Feed Consumption (g)	Energy Consumption (kcal)	Weight Gain (g)
Cellulose			
5%	135.8^{2} ± 10.1	546.0	16.7^{3} ± 8.0
10%	123.1^{1,2} ± 16.8	470.1	13.9^{2,3} ± 3.8
20%	118.3^{1,2} ± 20.0	404.6	11.5^{2,3} ± 4.5
Hemicellulose			
5%	101.0^{1,2} ± 20.9	406.1	7.2^{1,2} ± 3.5
10%	123.1^{1,2} ± 16.0	470.1	14.1^{2,3} ± 3.8
20%	103.6^{1,2} ± 16.5	354.4	8.8^{1,2} ± 3.4
Lignin			
5%	119.3^{1,2} ± 29.7	479.5	10.2^{1,2} ± 5.4
10%	114.4^{1,2} ± 21.5	437.0	8.9^{1,2} ± 4.0
20%	92.3^{1} ± 31.9	315.6	3.4^{1} ± 6.7

[a]Seven or eight mice per group. Different number superscripts indicate significantly different values ($p < 0.05$ level).

MATERIALS AND METHODS

The semipurified casein-based ration described in Table I was altered by additions of commercially available hemicellulose (Mucilose Flakes, ICN Nutritional Biochemicals Corp., Cleveland, OH), cellulose (Alphacel Nonnutritive Bulk, ICN Nutritional Biochemicals Corp.), and lignin (Indulin-AT, Wesvaco Polychemicals Dept., N. Charleston, SC), at the expense of starch. Each fiber source was added at 5, 10, or 20% of the ration.

Swiss White male weanling mice (Sasco Inc., Omaha, NE) were divided into nine groups of eight mice each and individually housed in randomly arranged metabolic cages so urine and feces could be collected. Individual mice were assigned to specific groups so that the initial mean starting weights of the groups were similar. During the week adjustment period before the start of the 28-day experiment, the mice consumed a standard 5% hemicellulose, 10% casein protein laboratory ration. Distilled water and feed were consumed *ad libitum*.

Mouse weight and feed consumption was recorded and feces and urine were collected weekly during the 28-day feeding trial. Urine was preserved by adding concentrated hydrochloric acid in the amount of 1% of the volume. No preservative other than freezing was used with the feces. At the end of the feeding trial, the mice were sacrificed using carbon dioxide and the carcasses were frozen for later analysis.

Weekly growth data and intakes of protein and fat were calculated for each mouse. Apparent digestibilities were determined for each of these components. The protein efficiency ratio (PER) values (modification of AOAC, 1975a) and feed efficiency ratio (FER) values were calculated to evaluate the protein and feed efficiency of the hemicellulose, cellulose, and lignin rations.

Nitrogen content of urine and feces were determined (Scales and Harrison 1920) on 28-day composites. Fat determinations also were done on 28-day feces composites (AOAC 1975b, Mickelsen and Anderson 1959). Nitrogen balances for each mouse were calculated.

A composite of the eight mouse carcasses from each experimental group was autoclaved for 20 min at 15-lb pressure and ground in a blender. Each composite was analyzed for nitrogen, fat, moisture, and ash content (AOAC 1975b, Mickelsen and Anderson 1959, Scales and Harrison 1920, Spiller and Amen 1976).

Statistical analyses used included one-way analysis of variance and Student-Newman-Kuels test, a comparison of means (Nie et al 1975, Senedecor and Cochran 1967).

RESULTS AND DISCUSSION

The group means for feed consumption, energy consumption, weight gain, FER, and PER are given in Tables II and III. No significant differences were found in feed consumption except between the mice fed 20% lignin and those fed 5% cellulose ($p < 0.05$). The mice tended to consume less ration as the percent of cellulose and lignin increased; thus both dilution and lower intake decreased energy intake. The mice fed 20% lignin consumed significantly less ration and thus gained considerably less weight. The cellulose diet results agree with results of Sundervalli et al (1971) who found no significant difference in ration consumption when the ration contained 5, 10, or 20% cellulose.

In a study by Bell (1960), however, as the percent of cellulose increased from 8 to 24% in the ration, the amount of ration consumed by weanling mice increased. That study indicated that, at ration levels below 24% cellulose, the mice could compensate for the lower energy concentration of the ration by consuming more.

Watt and Marcus (1964) administered sodium lignosulphate in drinking fluid to guinea pigs and as the amount of sodium lignosulphate consumed increased, weight gain decreased.

The mice fed hemicellulose did not follow the same trend as mice fed cellulose and lignin. The 10% hemicellulose group tended to consume more ration and thus tended to gain more weight than did the 5 or 20% groups. The 10% hemicellulose group apparently needed to consume more ration because less energy was available. The 20% group consumed less ration than the 10% group, suggesting that compensatory mechanisms observed with 10% hemicellulose were so overburdened that they became ineffective. The mice tended to scatter the ration more as the percent of fiber increased, an activity associated with decreased acceptance. Even so, the 20% group gained slightly more weight than did the mice fed 5% hemicellulose (Table II).

The mean FER values (grams of ration/grams of weight gain) for all nine groups were not significantly different (Table III). However, in the groups fed cellulose and lignin, the efficiency tended to decrease as the percent of fiber increased. Overall, the ability of mice to utilize the cellulose ration was more efficient than the ability of mice to utilize the hemicellulose or lignin rations (Table III). A reason might be the greater water binding capacity of hemicellulose per se or its ability to bind other nutrients in much the same way that it binds water. Several studies with humans indicate a greater negative effect on nitrogen, zinc, magnesium, copper, and fat of hemicellulose than of cellulose or pectin (Drews 1977, Kies and Fox 1978).

The mean PER values (gram weight gain per gram of protein consumed) of the mice fed 10% hemicellulose were significantly greater than for the mice fed 20% lignin ($p < 0.05$) (Table III). This would be expected, considering the feed consumption and weight gain data.

Our study used small groups of mice and statistically significant changes would be more difficult to obtain than in large groups, but some changes that are not statistically significant may be of biological interest. For the cellulose and lignin rations, PER values tended to decrease as the percent of fiber increased (Table III). Because the amount of energy available in rations decreased as the percent of fiber increased (Table II), protein probably was used increasingly as an energy source. The 20% hemicellulose ration had a higher PER value (1.9 g weight gain per gram of protein consumed) than did the 5% hemicellulose ration (1.1 g weight gain per gram of protein consumed). The difference cannot be explained by the energy consumption, because the group fed 20% hemicellulose had a lower energy availability (354.4 kcal/28 days) than the 5% hemicellulose group (406.1 kcal/28 days), assuming that hemicellulose is not utilizable. These data indirectly suggest, however, this species can use hemicellulose for energy, at least in part.

Table III presents mean total dry feces and mean percent dry

TABLE III
Influence of Dietary Fiber on Feed Efficiency and Feces Data

Ration Composition	Mean Values[a]			
	FER (g ration/ g wt gain)	PER (g wt gain/ g protein consumed)	Total Dry Feces (g/28 days)	Dry Matter of Feces (%)
Cellulose				
5%	8.3[1] ± 1.1	1.7[1,2,3] ± 0.2	13.5[1] ± 0.9	92.9[1,2] ± 2.2
10%	9.5[1] ± 2.8	1.7[1,2,3] ± 0.5	21.0[2,3] ± 2.3	92.3[1] ± 1.4
20%	11.3[1] ± 3.0	1.4[1,2] ± 0.3	29.7[4] ± 5.6	93.7[2] ± 0.3
Hemicellulose				
5%	15.5[1] ± 3.7	1.1[1,2] ± 0.3	15.0[1,2] ± 5.5	93.5[2] ± 0.5
10%	9.1[1] ± 1.9	2.3[3] ± 0.5	27.1[3,4] ± 5.3	94.2[2] ± 0.6
20%	12.9[1] ± 3.8	1.9[2,3] ± 0.7	30.6[4] ± 7.4	93.7[2] ± 0.4
Lignin				
5%	9.5[1] ± 4.0	1.2[1,2] ± 0.6	11.2[1] ± 3.7	96.2[3] ± 0.3
10%	15.5[1] ± 7.6	1.3[1,2] ± 0.4	18.0[1,2] ± 2.5	96.2[3] ± 0.3
20%	38.6[1] ± 71.7	1.0[1] ± 0.9	21.3[2,3] ± 8.2	95.8[3] ± 0.2

[a]Seven or eight mice per group. Different number superscripts indicate significantly different values ($p < 0.05$).

TABLE IV
Influence of Dietary Fiber on Nitrogen Balance in Mice

Ration Composition	Means (g N/day)[a]			
	Nitrogen Intake	Urinary Nitrogen Excretion	Fecal Nitrogen Excretion	Nitrogen Balance
Cellulose				
5%	0.08[2] ± 0.01	0.01[1,2] ± 0.003	0.01[1] ± 0.001	0.05[5] ± 0.007
10%	0.07[1,2] ± 0.01	0.01[1,2] ± 0.002	0.01[1] ± 0.001	0.05[4,5] ± 0.009
20%	0.07[1,2] ± 0.01	0.01[1] ± 0.003	0.02[1] ± 0.002	0.05[3,4,5] ± 0.01
Hemicellulose				
5%	0.06[1,2] ± 0.01	0.01[1] ± 0.004	0.02[1] ± 0.004	0.03[1,2,3] ± 0.004
10%	0.07[1,2] ± 0.01	0.01[1,2] ± 0.004	0.02[2] ± 0.004	0.04[1,2,3] ± 0.006
20%	0.06[1,2] ± 0.01	0.01[1,2] ± 0.005	0.02[2] ± 0.005	0.03[1,2] ± 0.006
Lignin				
5%	0.07[1,2] ± 0.02	0.01[1,2] ± 0.005	0.01[1] ± 0.003	0.04[3,4,5] ± 0.015
10%	0.07[1,2] ± 0.01	0.02[1,2] ± 0.006	0.01[1] ± 0.002	0.04[2,3,4] ± 0.009
20%	0.05[1] ± 0.02	0.02[2] ± 0.007	0.01[1] ± 0.004	0.02[1] ± 0.008

[a]Seven or eight mice per group. Different number superscripts indicate significantly different values ($p < 0.05$).

matter of feces for the nine ration groups. Increases in fecal weight were statistically significant with increased cellulose, hemicellulose, or lignin supplementation in spite of the tendency toward lower food consumption at higher levels of fiber additions. Differences in mean percent dry matter of feces were greater among fibers than at different levels of fiber supplementation, indicating a difference in water binding capacity. Lignin is an aromatic polymer of phenylpropanoid units with hydrophobic properties, which may account for the finding that feces of mice fed lignin had the highest percent of dry matter.

Mean nitrogen balances, mean fecal nitrogen excretion, mean urinary nitrogen excretion, and mean nitrogen intake of mice fed rations varying in kind and level of fiber supplementation are shown in Table IV.

Some statistically significant differences were observed. The mice fed 10 and 20% hemicellulose excreted significantly more nitrogen in feces than the other ration groups ($p < 0.05$). Other trends of possibly greater biological significance also were seen. In general, increases in dietary fiber resulted in trends toward higher fecal nitrogen loss. Hemicellulose seemingly had the most pronounced effect on increase in fecal nitrogen loss. Urinary nitrogen loss also tended to increase with increased intake of hemicellulose and lignin but not with increased levels of cellulose. As a result, nitrogen balances also tended to decrease with increased dietary fiber intake; negative effects were greater for lignin and for hemicellulose supplements than for cellulose (Table IV).

The mean percent apparent digestibility of protein (feed N − fecal N/feed N × 100) appeared to be most negatively affected by the hemicellulose additions (Table V). This might be related to greater protein binding capacity, greater effect on intestinal motility, greater diluting effect, or to other effects limiting digestion or absorption or both.

Another method of measuring nitrogen disappearance is that of protein utilization in which fecal nitrogen is subtracted from feed nitrogen. As shown in Table V, increase in fiber supplementation, regardless of the type of fiber, resulted in an apparent decrease in protein utilization, with hemicellulose having the greatest apparent effect. This too could be caused by the decrease in feed consumption with increased fiber additions.

Table VI shows the mean values for fat consumption, fecal fat excretion, fat utilization, percent apparent digestibility of fat, and percent fat of dry feces. Because rations were formulated to contain the same amount of fat, fat intake varied with differences in total ration intake. Thus, data on fat consumption followed the same trends as feed consumption.

Fecal fat excretion was calculated in two ways, total fecal fat excretion for 28 days and percent fat in dry feces (Table VI). The total fecal fat excretion of the 10% hemicellulose group (5.1 g of fat/28 days) was significantly greater than that of all other groups ($p < 0.05$). The 5 and 20% hemicellulose groups had the next highest fecal fat excretion (3.3 g and 3.4 g of fat/28 days, respectively) and were both significantly different from the remaining seven groups ($p < 0.05$).

The 5 and 10% hemicellulose rations had significantly greater percent fat of dry feces (19.8 and 18.2%, respectively) than the other ration groups ($p < 0.05$) (Table VI). As the percent of fiber increased, the percent fat of dry feces decreased for all three fibers. Although ration intake varied, the percent fat in rations remained the same. If fiber binds fat, the percent fat of feces would be expected to increase with increases in total dietary fiber. This clearly was not the case.

Even though percent fat of dry feces tended to decrease with increased amounts of dietary fiber regardless of fiber fed, these figures did not correlate well with mean total grams of fat excreted

TABLE V
Influence of Fiber on Protein Digestibility in Mice

Ration Composition	Mean Values[a] Apparent Protein Digestibility (%)	Protein Utilized (g protein/day)
Cellulose		
5%	86.7[5] ± 0.7	0.42[3] ± 0.03
10%	82.2[4,5] ± 2.5	0.36[2,3] ± 0.06
20%	77.5[3] ± 3.9	0.33[1,2,3] ± 0.07
Hemicellulose		
5%	74.4[3] ± 2.6	0.27[1,2] ± 0.05
10%	67.0[2] ± 3.7	0.29[1,2] ± 0.04
20%	62.0[1] ± 6.1	0.23[1] ± 0.04
Lignin		
5%	84.6[5] ± 4.1	0.36[2,3] ± 0.11
10%	78.5[3,4] ± 4.4	0.32[1,2] ± 0.07
20%	74.4[3] ± 2.9	0.25[1] ± 0.09

[a]Seven or eight mice per group. Different number superscripts indicate significantly different values ($p < 0.05$).

TABLE VI
Influence of Dietary Fiber on Fat Digestibility in Mice

Ration Composition	Mean Values[a] Total Fat Consumption (g/28 days)	Total Fecal Fat Excretion (g/28 days)	Fat Utilized (g/28 days)	Apparent Digestibility of Fat (%)	Fat of Dry Feces (%)
Cellulose					
5%	13.6[2] ± 1.0	1.0[1] ± 0.2	12.6[3] ± 1.1	92.8[2] ± 1.8	7.2[1,2] ± 0.02
10%	12.3[1,2] ± 1.7	1.4[1] ± 0.5	10.9[2,3] ± 1.6	88.8[2] ± 3.8	6.4[1,2] ± 0.02
20%	11.8[1,2] ± 2.0	1.3[1] ± 0.3	10.6[2,3] ± 2.0	89.0[2] ± 2.4	4.5[1] ± 0.01
Hemicellulose					
5%	10.1[1,2] ± 2.1	3.3[2] ± 2.7	6.8[1] ± 1.6	69.4[1] ± 18.9	19.8[3] ± 0.09
10%	12.3[1,2] ± 1.6	5.1[3] ± 2.3	7.2[1] ± 1.7	59.5[1] ± 15.5	18.2[3] ± 0.06
20%	10.4[1,2] ± 1.7	3.4[2] ± 1.5	7.0[1] ± 1.2	68.0[1] ± 10.9	10.7[2] ± 0.02
Lignin					
5%	11.9[1,2] ± 3.0	1.5[1] ± 0.9	10.5[2,3] ± 3.0	88.5[2] ± 5.7	11.9[2] ± 0.05
10%	11.4[1,2] ± 2.2	1.4[1] ± 0.3	10.1[2,3] ± 2.2	87.5[2] ± 3.6	7.8[1,2] ± 0.02
20%	9.2[1] ± 3.2	1.0[1] ± 0.5	8.3[1,2] ± 2.8	90.2[2] ± 3.4	4.3[1] ± 0.01

[a]Seven or eight mice per group. Different number superscripts indicate significantly different values ($p < 0.05$).

(Table VI). Total fat excreted seemed to be more directly related to total fat intake.

Fat utilization (fat consumed − fecal fat) (Table VI) of the mice fed 5, 10, or 20% hemicellulose was significantly less than that of the remaining groups except the 20% lignin group ($p < 0.05$). Some trends for decreased fat utilization with increased fiber intake regardless of kind of fiber were noted.

The mice fed 5, 10, or 20% hemicellulose rations had significantly lower mean percent apparent fat digestibility values than the other six groups ($p < 0.05$) (Table VI). In the mice fed cellulose and hemicellulose, the percent apparent digestibility of fat tended to decrease as the percent of fiber increased. In those fed lignin, as the percent of lignin increased, the percent apparent digestibility of fat tended to first decrease but then to increase.

Spiller and Amen (1976) observed that Solka-floc, a cellulose product, resulted in greater excretion of fecal lipids when compared with slippery elm bark. Balmer and Zilversmit (1974) found the opposite in that an unpurified plant fiber caused greater excretion of fecal lipids than a purified plant fiber. The characteristics of each kind of fiber exert a different effect on fecal fat excretion.

Some changes were found in carcass composition of mice fed rations varying in kind and level of fiber. All carcasses for each ration group were composited for determination of percent protein, fat, moisture, and ash. Results of these analyses are shown in Table VII. These figures were applied to individual mouse carcass weights (Table VIII) for approximate determination of gram composition of each mouse. Carcass composition data are shown as metabolic body size (Kleiber 1975), ie, fat-free body weight in kilograms to the 0.75 power.

Percent protein carcass composition values (Table VII) varied, with mice fed hemicellulose showing slightly lower protein values than those of mice fed cellulose or lignin. Carcass protein per metabolic body size reflected the size of the carcass, with smaller carcasses having smaller values.

A trend toward lower percent fat composition was seen in mice fed increased levels of cellulose and hemicellulose (Table VII). This also was reflected in fewer grams of carcass fat per metabolic body size (Table VIII). These findings agree with data of Sundervalli et al (1971), which indicated that rats fed 20% cellulose had lower carcass fat content than rats fed 5 or 10% cellulose.

As would be expected, carcass moisture and fat composition were directly related. This was also true of carcass ash data (Table VIII).

That smaller mice would have smaller amounts of all compositional measurements is only reasonable; hence, percentage composition figures as given in Table VII are more meaningful for comparisons. Slight increases in percentage moisture composition with increased dietary cellulose were observed; however, data for mice fed hemicellulose and lignin were inconsistent in direction. Percent ash composition for the cellulose fed groups decreased with increased feeding of this fiber, but again results were inconsistent for the hemicellulose and cellulose groups. Percent protein composition for mice fed the hemicellulose and lignin showed trends toward decreased levels as the percent of fiber increased in the ration. The mice fed cellulose showed a tendency toward increased percentage of protein as the percent of fiber increased in the ration. Mice fed cellulose and lignin had decreased carcass fat composition percentages as the percent of fiber increased in the ration (Table VIII).

The mouse carcasses were frozen to preserve them for further analysis. The carcasses were later thawed and livers were examined. No abnormalities were observed among the mice fed cellulose and hemicellulose, but abnormal coloration was noted among mice fed lignin. The livers were darker toward the proximal ends but darkly speckled and lighter colored toward the distal ends. The degree of the abnormality was more pronounced as the percent of lignin in

TABLE VII
Influence of Dietary Fiber on Mouse Carcass Composition

Ration Composition	Mean Values[a,b]			
	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Cellulose				
5%	16.9	23.0	56.6	2.1
10%	15.2	19.8	58.9	1.5
20%	17.8	20.5	59.7	1.7
Hemicellulose				
5%	16.6	14.0	66.9	1.3
10%	15.0	16.7	64.8	1.6
20%	16.3	10.6	69.9	1.2
Lignin				
5%	18.1	17.1	61.6	1.5
10%	17.2	16.1	63.1	1.4
20%	17.5	17.3	60.7	1.5

[a]Seven or eight mice per group. Methodology described by Mickelsen and Anderson (1959).

TABLE VIII
Influence of Dietary Fiber on Carcass Weights and Composition

Ration Composition	Mean Values[a]				
	Carcass Weight (g)	Carcass Protein (g protein/wt$^{.75}$)	Carcass Fat (g fat/wt$^{.75}$)	Carcass Moisture (g water/wt$^{.75}$)	Carcass Ash (g ash/wt$^{.75}$)
Cellulose					
5%	$33.9^{3} \pm 3.3$	$2.4^{3} \pm 0.2$	$3.2^{6} \pm 0.2$	$7.9^{2} \pm 0.6$	$0.29^{4} \pm 0.02$
10%	$30.9^{2,3} \pm 4.3$	$2.0^{1,2} \pm 0.2$	$2.6^{5} \pm 0.3$	$7.7^{2} \pm 0.8$	$0.20^{3} \pm 0.02$
20%	$29.1^{2,3} \pm 5.0$	$2.2^{2,3} \pm 0.3$	$2.6^{5} \pm 0.3$	$7.5^{2} \pm 1.0$	$0.21^{3} \pm 0.03$
Hemicellulose					
5%	$24.4^{1,2} \pm 5.1$	$1.8^{1,2} \pm 0.3$	$1.5^{2} \pm 0.2$	$7.3^{2} \pm 1.1$	$0.14^{1} \pm 0.02$
10%	$30.2^{2,3} \pm 3.5$	$1.9^{1,2} \pm 0.2$	$2.1^{4} \pm 0.2$	$8.3^{2} \pm 0.7$	$0.20^{3} \pm 0.02$
20%	$25.5^{1,2} \pm 3.4$	$1.8^{1,2} \pm 0.2$	$1.2^{1} \pm 0.1$	$7.9^{2} \pm 0.8$	$0.14^{1} \pm 0.01$
Lignin					
5%	$28.1^{2,3} \pm 5.9$	$2.2^{2,3} \pm 0.4$	$2.1^{4} \pm 0.3$	$7.5^{2} \pm 1.3$	$0.18^{2,3} \pm 0.03$
10%	$26.3^{1,2} \pm 4.0$	$2.0^{1,2} \pm 0.2$	$1.9^{3,4} \pm 0.2$	$7.3^{2} \pm 0.8$	$0.16^{1,2} \pm 0.02$
20%	$21.4^{1} \pm 6.6$	$1.7^{1} \pm 0.4$	$1.7^{2,3} \pm 0.4$	$6.0^{1} \pm 1.4$	$0.14^{1} \pm 0.03$

[a]Seven or eight mice per group. Different number superscripts indicate significantly different values ($p < 0.05$).

the ration increased. No attempt was made to quantify this observation and no statistical analysis was performed.

A possible explanation for this abnormality might be that the lignin was being absorbed by the mice. Lignin, a phenolic compound, would be detoxified by the liver. This detoxification process could cause the color change, either bleaching or darkening the liver in proportion to the percent of lignin in the ration. Impurities in the lignin product also might be a causative agent. Britton earlier observed similar abnormalities in rats fed lignin.[2]

The response to feeding variable levels of hemicellulose, cellulose, and lignin are not identical. In general, as the level of fiber increases, feed consumption decreases as does weight gain, feed efficiency, protein efficiency, nitrogen balance, apparent digestibilities of protein and fat, percent of fat in feces, and percent carcass fat. Total fecal fat, fecal nitrogen, and total fecal dry weight tend to increase with increased levels of fiber in the rations. Liver abnormalities of coloration occur in mice fed lignin but not in those fed cellulose or hemicellulose.

[2]Personal Communication, R. A. Britton, Department of Animal Science, University of Nebraska, Lincoln, NE, 1977.

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