Effect of Age and Diet on the Digestibility of Gross Components and Dietary Fiber in Rats

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Insoluble dietary fiber is defined methodologically as cellulose, hemicellulose and lignin in food components.1) The microflora of the large intestine is able to partly ferment dietary fiber constituents, but the extent of fermentation is quite variable among various types of dietary fibers. It is unclear whether insoluble dietary fiber can be digested similarly in young and adult rats, and whether the same digestibility of dietary fiber as that in rats fed less digestible diets is obtained in rats fed highly digestible diets and then changed to such less digestible diets. The present study was undertaken to provide information on the extent of digestibility of insoluble dietary fiber for rats at different ages and dietary conditions.

The detailed experimental procedure has been described in a previous report.2) Inbred Fischer male rats weighing approximately 87 g (5 weeks of age) in the 1st experiment and 259 g (11 weeks of age) in the 2nd experiment were used, with a preliminary period of 7 days from 4 or 10 weeks of age and thereafter a balance period of 7 days. The rats in group A were given an autoclaved practical diet based on corn-soybean meal (diet L-4853) throughout the experimental period. The rats in group B were given an autoclaved purified diet based on casein-corn starch (diet L-488F)4-5) until 9 weeks of age and thereafter the diet was changed to the autoclaved practical diet. The diet L-488F used in this experiment was supplemented with 5% cellulose (Toyo filter paper for feed, No. D, 40~60 mesh, Toyo Roshi Co., Ltd., Tokyo) instead of cellophane spangles. The feces were collected daily and dried with circulating air at 60°C after spraying with 10% HCl. The diets and dried feces were ground finely and kept in a refrigerator.

The official methods of the A.O.A.C.6) were used for determination of the gross chemical compositions. Neutral
**Table I. Chemical Composition of Experimental Diets** (% of dry matter)

<table>
<thead>
<tr>
<th>Diet</th>
<th>Crude ash</th>
<th>Organic matter</th>
<th>Crude protein</th>
<th>Crude fat</th>
<th>Nitrogen-free extract</th>
<th>Crude fiber</th>
<th>NDF&lt;sup&gt;a&lt;/sup&gt;</th>
<th>ADF&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Hemicellulose</th>
<th>Cellulose</th>
<th>Lignin</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-485</td>
<td>5.89</td>
<td>94.11</td>
<td>25.11</td>
<td>6.08</td>
<td>59.04</td>
<td>3.88</td>
<td>15.46</td>
<td>6.78</td>
<td>8.68</td>
<td>4.14</td>
<td>2.64</td>
</tr>
<tr>
<td>L-488F</td>
<td>2.24</td>
<td>97.76</td>
<td>24.38</td>
<td>4.78</td>
<td>65.76</td>
<td>2.84</td>
<td>13.48</td>
<td>5.48</td>
<td>8.00</td>
<td>5.09</td>
<td>0.39</td>
</tr>
</tbody>
</table>

<sup>a</sup> Neutral detergent fiber.

<sup>b</sup> Acid detergent fiber.

**Table II. Apparent Digestibility of Diets (%)** (Means ± standard errors)

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Group&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Dry matter</th>
<th>Crude ash</th>
<th>Organic matter</th>
<th>Crude protein</th>
<th>Crude fat</th>
<th>NDF&lt;sup&gt;b&lt;/sup&gt;</th>
<th>ADF&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Hemicellulose</th>
<th>Cellulose</th>
<th>Lignin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>A</td>
<td>84.3±1.1</td>
<td>68.6±2.0</td>
<td>85.2±1.1</td>
<td>79.1±1.6</td>
<td>89.5±0.5</td>
<td>52.4±0.9</td>
<td>45.8±2.5</td>
<td>60.3±1.8</td>
<td>26.1±3.5</td>
<td>76.8±1.1</td>
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<tr>
<td></td>
<td>B</td>
<td>93.1±0.2</td>
<td>89.5±0.4</td>
<td>93.2±0.2</td>
<td>92.0±0.5</td>
<td>95.1±0.4</td>
<td>61.4±1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd</td>
<td>A</td>
<td>82.3±0.4</td>
<td>56.0±1.3</td>
<td>84.2±0.4</td>
<td>78.1±0.8</td>
<td>88.6±0.4</td>
<td>46.6±1.2</td>
<td>38.9±1.5</td>
<td>52.6±1.7</td>
<td>19.1±1.7</td>
<td>70.0±1.2</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>81.6±0.7</td>
<td>58.0±1.6</td>
<td>82.8±0.7</td>
<td>76.9±0.8</td>
<td>88.3±0.9</td>
<td>44.7±1.3</td>
<td>31.7±1.7</td>
<td>55.0±1.5</td>
<td>8.2±2.4</td>
<td>68.4±1.7</td>
</tr>
</tbody>
</table>

Statistical summary:

<table>
<thead>
<tr>
<th>Statistical summary</th>
<th>1st (A x B)</th>
<th>A (1st x 2nd)&lt;sup&gt;d&lt;/sup&gt;</th>
<th>2nd (A x B)</th>
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<tbody>
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<td></td>
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</table>

<sup>a</sup> Group A was fed diet L-485 (practical diet) throughout the experimental period, and group B was fed diet L-488F (purified diet) until 9 weeks of age and thereafter the diet was changed to L-485.

<sup>b</sup> Neutral detergent fiber.

<sup>c</sup> Acid detergent fiber.

<sup>d</sup> Paired sample t-test was used.

* Significant difference at $p<0.05$.

** Significant difference at $p<0.01$. 
detergent fiber (NDF) after starch removal by enzymatic digestion according to a modification (Fig. 1)7 of the method of Mori and Aragane; acid detergent fiber (ADF) and lignin were determined by the detergent procedures9 which Van Soest and his coworkers developed. Hemicellulose was estimated as the difference between NDF and ADF. Cellulose content was calculated by subtracting the lignin % from the ADF %.

Since nitrogen contamination of NDF residues from the diet and feces of animals10 and human subjects'12,13 has been reported, the experiment assessed the ability of the neutral and acid detergent procedures used in this experiment to remove nitrogen from NDF and ADF residues. The results showed that the NDF and ADF residues of the experimental diets and feces contained very little nitrogen (<0.1%). Therefore, the NDF and ADF values analysed were not corrected for the protein content.

The differences between groups A and B were analysed for statistical significance by student's t-test, and the paired sample t-test was used for data obtained from the same animals in the same group (comparison of the 1st and 2nd experiments in each group). The difference between the means was considered significant if p<0.05.

Analyses of the gross chemical compositions and insoluble dietary fiber are presented in Table I. NDF content and the proportion of hemicellulose, cellulose and lignin in the NDF were roughly similar to the results of Wise and Gilburn14 who analysed commercial diets for mice and rats.

It is well known that in various foods the NDF content is much higher than the crude fiber content,9,15 and this tendency was seen for both the practical and the purified diet used in this study. As shown in Table I, the purified diet contained 8% hemicellulose and 0.4% lignin which were not supplemented in this diet. While Nyman and Asp16 suggested that a small amount (0.8%) of dietary fiber in maize starch is present, Varo et al.17 observed that thermal processing of the starch increased the dietary fiber, e.g., NDF content was 1.8% in raw potatoes and increased to 3.2% by autoclaving the potatoes. Therefore, it is probable that autoclaving of the purified diet, at least in part, might bring about increased hemicellulose and lignin.

Apparent digestibilities of the experimental diets are summarized in Table II. Owing to the small amount of feces excreted by rats fed the purified diet, only NDF was analysed with respect to insoluble dietary fiber fractions for group B in the 1st experiment. From the comparison between groups A and B in the 1st experiment, it was observed that the purified diet had much higher digestibility than the practical diet concerning gross components and NDF of the diets.

In the insoluble dietary fiber fractions, NDF digestibilities in all three groups fed the practical diet examined were ca. 50%, a value similar to the results of Ranhottra et al.18 on young adult rats. These were higher than ADF digestibilities in the respective groups (p<0.05). Moreover, hemicellulose was more than twice as digestible as cellulose (p<0.001), and the same tendencies were already obtained in rats fed diets containing hay.11,19 Hove and King13 observed that 29% of cellulose was digested by young rats fed a purified diet with 5% cellulose, and our study showed that young rats fed the practical diet (group A in the 1st experiment) digested 26% of the cellulose. Therefore, it might be possible that young rats have the ability to digest cellulose of both origins similarly from the purified and practical diets.

It is generally recognized that lignin is the least digestible component of plants20 and practically unaffected by microbial fermentation.14 Nyman and Asp16 observed that digestibility of wheat bran lignin was 9% in rats. However, there is a report that lignin in corn cobs is extensively solubilized and presumably digested throughout the digestive tract of lambs.21 In the present experiment, lignin seemed less resistant to gut microbial degradation than hemicellulose and cellulose. It is probable that this high digestibility of lignin may result partly from formation of soluble lignin-carbohydrate complexes which might not be measured in the fecal lignin fraction,22 and there are observations22,24 that the composition of the remaining lignin after digestion by the sheep is altered. Therefore, it is expected that further studies will be directed towards differentiating fecal materials which are determined as lignin according to the acid detergent lignin method used in our experiment.

Comparison between the 1st and 2nd experiments in group A fed the practical diet showed higher digestibility for younger rats only with crude ash among the gross components. With respect to insoluble dietary fiber, however, all of the dietary fiber fractions analysed showed higher digestibilities in young animals, although no significant difference was observed in digestibility of cellulose. Brauer et al.13 also found a higher tendency of NDF digestibility in young adult humans than in elderly men.

From the comparison between group A, continuously fed a practical diet, and group B fed a purified diet prior to change to the practical diet in the 2nd experiment, it was observed that no differences were obtained in the digestibilities of the dietary gross components. On the other hand, significantly higher digestibilities of ADF and cellulose were found in group A than in group B. This observation shows the possibility that the digestibilities of ADF, especially cellulose, in the animals fed highly digestible diets are aggravated when the animals were changed to less digestible diets.

Results obtained from the present experiment showed that dietary NDF content was ca. 15% and its digestibility was ca. 50%. Therefore, it is postulated that appreciable amounts of the degradation products of NDF are available to the rats through the absorption from the large intestine directly or from the upper intestine after recycling of feces by coprophagy.

The present study showed; (1) that on digestibility to
rats fed the practical diet, NDF tended to be higher than ADF and hemicellulose also higher than cellulose; (2) that lignin in the practical diet is not an indigestible material for rats; (3) that compared with older rats, younger rats had significantly higher digestibilities of crude ash, NDF, ADF, hemicellulose and lignin; and (4) that young rats fed purified diet for 6 weeks digested less ADF, especially cellulose, when fed the practical diet than those given the same practical diet continuously.

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REFERENCES