AVAILABILITY OF AMINO ACIDS IN VIVO*

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It has been known for many years that free amino acids are present in the blood and that their concentration increases after ingestion of a meal. In 1912 Van Slyke and Meyer (1) reported the presence of amino nitrogen in the non-protein fraction of the blood of dogs and that its concentration increased after feeding meat. Abel et al. (2), using a vivi-diffusion apparatus, observed that free amino acids are transported as such in the blood. Shortly after Abel’s results were published, Abderhalden (3) reported the isolation of a considerable quantity of free amino acids from the blood.

In 1906 Howell (4) reported that the concentration of amino acids in the portal vein was greater than that in the jugular vein after ingestion of a meal. He also reported the presence of free amino acids in the blood of dogs that had been fasted for 60 hours.

In 1949 Dent and Schilling (5) suggested that proteins may be only partially hydrolyzed in the intestinal tract. They theorized that, although an increase in the concentration of free amino acids in the systemic blood could be detected after ingestion of a meal, a large portion of the protein might be transported to the tissues as peptides. The tissues could utilize these peptides by converting them into new proteins and discarding the unneeded amino acids, thus causing a rise in the free amino acids of the blood plasma. They (5) successfully cannulated the portal vein of dogs and collected blood at various times after feeding different sources of protein. Analyses of these samples (5, 6) revealed a slight increase in the conjugated amino acids in the blood plasma from the portal vein but a much greater increase in the concentration of free amino acids. These conjugated amino acids were not necessarily fragments of the proteins ingested, since the feeding of L-glutamic acid produced increases in the conjugates of the plasma.

This work was confirmed in 1951 by Parshin and Rubel (7) who found no evidence for the absorption of peptides through the intestinal wall.

Undoubtedly, proteins are, for the most part, hydrolyzed to amino acids which are absorbed and transported as such in the blood.

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After successfully cannulating the portal vein of dogs (8), studies were begun to determine whether there was a difference in the time and extent of absorption of amino acids after feeding different proteins.

**EXPERIMENTAL.**

Because of the various experimental procedures used in the following studies, experiments will be described separately. All dogs were maintained on the complete semipurified ration recommended by Campbell (9) which has the following composition, in gm.: sucrose, 687; casein,1 190; Salts 4 (10), 40; cottonseed oil, 110; choline, 1.66; and vitamin mixture,2 1.

The test meals were fed and blood was collected and analyzed as described by Denton et al. (8). The ration previously mentioned was fed when the digestion of casein was being studied, and, when zein3 and beef4 were used, these two proteins were substituted for casein to give the same nitrogen intake. The fat present in the meat replaced part of the cottonseed oil in order that the fat content remain at the same level in all rations.

Dog 102—150 gm. of ration containing zein as the source of protein were fed to Dog 102 after his portal vein had been cannulated according to the method of Denton et al. (8). The results of the amino acid analyses of the blood plasma are presented in Table I. A decrease in the concentration of the amino acids measured occurred at 1 and 1.5 hours after feeding zein, but an increase, with the exception of lysine, occurred at 5 hours. The reason for the decrease in the concentration of amino acids in the blood plasma from both veins is not known; however, zein does have a very low concentration of most of the essential amino acids. The same results have been obtained in previously conducted experiments with zein. The time of sampling may be very important, since the concentration of amino acids in the blood plasma may not exhibit a gradual increase and decrease after ingestion of a meal.

Dog 102A—After feeding zein twice and finding this unusual absorption pattern, 150 gm. of a casein ration were fed and blood was withdrawn from the portal and radial veins before (0 hour), 1, 2.5, and 5 hours afterwards. Amino acid analyses were made on the protein-free blood plasma and the

1 Vitamin-free test casein, General Biochemicals, Inc., Chagrin Falls, Ohio.
2 Each 1 gm. portion of the vitamin mixture in a sucrose base contained 3.3 mg. of thiamine hydrochloride, 3.3 mg. of riboflavin, 2.0 mg. of pyridoxine hydrochloride, 66.0 mg. of niacin, 10.6 mg. of calcium pantothenate, 0.50 mg. of biotin, 0.44 mg. of folic acid, 0.02 mg. of vitamin B12. 5 drops of halibut liver oil were administered each week by a dropper.
3 Nutritional Biochemicals Corporation, Cleveland, Ohio.
4 Beef chuck that was purchased at a local meat market, trimmed of excess fat, and roasted in an electric roaster. The roasted meat was then ground in a meat grinder, dried 24 hours in hot air driers, and ground in a Wiley mill.
results, presented in Table II, were obtained. 1 hour after feeding casein, an increase in the concentration of all amino acids measured occurred in the blood plasma from the portal and radial veins. Since these same results have also been observed previously, it appears that there is a difference in the absorption of amino acids after feeding zein and casein.

Preliminary studies have been conducted in which casein was fed at a
concentration of 16 per cent of the ration and zein at 32 per cent. An increase in the concentration of amino acids was noted 0.5 hour after feeding.

**Table III**

*Concentration of Amino Acids in Blood Plasma after Feeding Beef to Dog 103*

The figures are in micrograms per ml. of plasma.

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>0 hr.</th>
<th>1 hr.</th>
<th>2.5 hrs.</th>
<th>4.5 hrs.</th>
<th>6 hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>17.8</td>
<td>16.5</td>
<td>26.0</td>
<td>16.6</td>
<td>43.2</td>
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<tr>
<td>Histidine</td>
<td>7.5</td>
<td>7.6</td>
<td>12.2</td>
<td>8.2</td>
<td>18.9</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>8.5</td>
<td>6.5</td>
<td>19.7</td>
<td>9.1</td>
<td>39.9</td>
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<tr>
<td>Leucine</td>
<td>7.5</td>
<td>10.8</td>
<td>21.5</td>
<td>14.3</td>
<td>45.5</td>
</tr>
<tr>
<td>Lysine</td>
<td>17.1</td>
<td>19.4</td>
<td>31.6</td>
<td>22.2</td>
<td>58.5</td>
</tr>
<tr>
<td>Methionine</td>
<td>4.3</td>
<td>3.1</td>
<td>8.5</td>
<td>5.7</td>
<td>14.4</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>7.7</td>
<td>7.5</td>
<td>13.8</td>
<td>8.7</td>
<td>27.0</td>
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<td>Threonine</td>
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<td>7.3</td>
<td>14.5</td>
<td>8.7</td>
<td>24.3</td>
</tr>
<tr>
<td>Tryptophan</td>
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<td>6.8</td>
<td>12.2</td>
<td>8.6</td>
<td>16.5</td>
</tr>
<tr>
<td>Valine</td>
<td>13.2</td>
<td>12.6</td>
<td>22.2</td>
<td>14.3</td>
<td>44.9</td>
</tr>
</tbody>
</table>

**Table IV**

*Concentration of Amino Acids in Blood Plasma after Feeding Zein to Dog 103*

The figures are in micrograms per ml. of plasma.

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>0 hr.</th>
<th>1.5 hrs.</th>
<th>4 hrs.</th>
<th>6 hrs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portal vein</td>
<td>Radial vein</td>
<td>Portal vein</td>
<td>Radial vein</td>
</tr>
<tr>
<td>Arginine</td>
<td>21.8</td>
<td>22.5</td>
<td>16.8</td>
<td>19.6</td>
</tr>
<tr>
<td>Histidine</td>
<td>10.1</td>
<td>9.4</td>
<td>7.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Isoleucine</td>
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<td>11.0</td>
<td>6.9</td>
<td>3.8</td>
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<tr>
<td>Leucine</td>
<td>14.6</td>
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<td>18.3</td>
<td>8.4</td>
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<tr>
<td>Lysine</td>
<td>22.8</td>
<td>23.1</td>
<td>14.9</td>
<td>15.8</td>
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<tr>
<td>Methionine</td>
<td>5.2</td>
<td>4.9</td>
<td>3.6</td>
<td>2.9</td>
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<tr>
<td>Phenylalanine</td>
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<td>12.0</td>
<td>9.3</td>
<td>8.8</td>
</tr>
<tr>
<td>Tryptophan</td>
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<td>8.6</td>
<td>5.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Valine</td>
<td>20.9</td>
<td>21.4</td>
<td>10.3</td>
<td>9.2</td>
</tr>
</tbody>
</table>

casein, while no increase was observed at 1.5 hours after feeding zein. Samples of blood in these experiments were withdrawn every 0.5 hour and only for 1.5 hours after feeding.

*Dog 103*—This was a 20 kilo mongrel dog on which comparative studies were made with beef and zein. *Dog 103* was maintained on the casein.
ration discussed previously and was fed the test meal in the usual manner. 200 gm. of the beef ration were fed 2 weeks after the cannula was inserted and the same amount of zein ration 2 weeks later. The results from the beef experiment are reported in Table III and those from zein in Table IV. By comparing the values in these two tables, it can be observed that there is a marked difference among the amino acid concentrations in the blood plasma following the ingestion of beef and zein. Samples of blood were withdrawn at different times after feeding these two proteins, since the increase in the concentration of amino acids in the blood plasma had been previously observed to occur much sooner after feeding beef than zein.

The peak of absorption for the amino acid after feeding beef appears to be at 2.5 hours, although an increase in the concentration occurred at 1 hour.

There was no significant increase in the concentration of amino acids in the blood plasma from the portal vein after feeding zein until 4 hours. The concentration of phenylalanine and leucine did increase slightly at 1.5 hours. The concentration of all amino acids with the exception of lysine increased from the 1.5 to 4 hour sample after feeding zein. Isoleucine, leucine, and phenylalanine occur in higher concentrations in zein than the other seven amino acids and it can be seen that these three amino acids show the greatest increase from the 1.5 to 4 hour samples.

This experiment was repeated on another dog and samples of blood were withdrawn at the same times after feeding the two proteins. Essentially the same results were obtained; the concentration of most of the amino acids remained the same or increased slightly at 1.5 hours, decreased slightly at 4 hours, but increased markedly at 6 hours after feeding beef. After feeding zein, they decreased markedly at 1.5 and 4 hours but increased at 6 hours.

DISCUSSION

Although the reason for the decrease in the concentration of amino acids after feeding zein has not been determined, it is believed to be due, at least in part, to the absorption of carbohydrates before amino acids are liberated from the protein. Studies have revealed that the non-reducing sugar content of the blood increased considerably 0.5 hour after feeding the test meals. Munro and Thomson (11) demonstrated that feeding glucose to fasting humans lowered the concentration of blood amino nitrogen as well as the concentration of the essential amino acids. They also observed that fat did not produce this effect. It seems possible that the carbohydrate moiety of the ration containing zein as a source of protein may be absorbed before the amino acids, thus causing a decrease in their concentration.
The concentration of amino acids in the portal vein increased soon after feeding casein or beef. The increases appeared to be proportional to the amounts of amino acids supplied by the protein, indicating similar availability of the amino acids.

**SUMMARY**

1. The concentrations of amino acids in the blood plasma from the portal vein decreased before showing an increase after feeding zein. The increase was proportional to the amounts supplied by the protein.
2. The concentrations of amino acids in the portal vein increased rapidly after feeding beef or casein. Again, this increase was proportional to the amounts supplied by the proteins. The amino acids from these two proteins enter the portal vein within a narrow enough period to allow maximal utilization.

**BIBLIOGRAPHY**

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