Note

Comparative Effect of Proteins, Peptides, and Amino Acid Mixtures on Recovery from 70% Hepatectomy in Rats

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Summary The effects of proteins, peptides, and amino acid mixtures on the recovery from 70% hepatectomy were compared in rats. In Experiment 1, the most suitable time for the comparison was studied. Rats weighing 250 g after 70% hepatectomy were fed 20% casein diet. On day 0, 1, 2, 3, 4, 6, 8, 11, 15 post-operation, 3–5 rats were killed for the observation of recovery. The recovery time, evaluated by daily food intake, body weight gain, liver weight and compositions, and hematologic values was about 10 days. For the comparison of different nitrogen sources, we estimated that the 6th day after the operation when the animals did not fully recover was suitable. In Experiment 2, rats of each group after hepatectomy were fed one of 14 experimental diets containing protein (3 types), peptides (8 types), or amino acid mixture (3 types) for 5 days and killed on the 6th day after the operation. Daily food intake, body weight gain, liver weight and compositions, and hematologic values were measured and pathological examination was also done. The effect of different nitrogen sources were similar on the recovery after 70% hepatectomy with only a few minor exceptions in rats.

Key Words protein, peptide, amino acid mixture, protein hydrolysate, hepatectomy, rat

There are many comparative studies on the utilization of protein, protein hydrolysates (peptides), and amino acid mixture in normal and under surgical stress rats; however, the results are contradictory. Many researchers (1, 2) reported the superior utilization of peptides to amino acid mixtures and proteins. However, our laboratory (3) and some other researchers (4–7) reported the similar utilization of them. As for the reason of the better utilization of peptides from other nitrogen sources, Silk et al. (1, 2) estimated the fast and well-balanced
Recovery of liver after hepatectomy in rats can be a good indicator for the evaluation of different nitrogen sources, because the recovery is mainly due to the protein synthesis. In our previous study we compared the recoveries among protein, peptide, and amino acid mixture (3) in hepatectomized rats but could not see the difference among them. The possible problem of our experiment, if there was one, was the observation time after the hepatectomy (15 days). The time was decided from the report of Higgins and Anderson (9); however, the recovery of the body weight in our previous experiment (3) was made in about a week, which appears contradictory to the reported time of Higgins and Anderson (9). If the observation time is too long after the operation, all the animals in various dietary conditions can fully recover and the comparison cannot be made. Therefore in Experiment 1, we tried to find the most suitable time for the comparison of recovery after 70% hepatectomy. In Experiment 2, the effect of the various nitrogen sources were compared in 70% hepatectomized rats based on the result of Experiment 1.

Materials and methods. Experiment 1: 1. Animals and diets—Male rats of Wistar strain weighing about 200 g were purchased from a breeder (Kyudo Company, Kumamoto). They were fed a commercial stock diet until their body weight became about 250 g. After a 24 h fast, about 70% of the liver of each rat was resected by the method described below. From the next day after the operation, the animals were fed experimental diet ad libitum up to 15 days maximum. The diet contained 23.4% casein (crude protein 91%), 0.3% methionine, 42.2% α-starch, 21.1% sucrose, 5% soybean oil, 5% mineral mixture, 2% cellulose, and 1% vitamin mixture. Compositions of the mineral and vitamin mixtures were the same as shown elsewhere (3). The rats were kept in separate cages with a 12 h light-dark cycle. Food and water were renewed every morning, and the body weight, and amount of food intake were weighed. The day before the operation, 5 rats were killed as a control group. On day 0,1,2,3,4,6,8,11, and 15 post-operation, 3–5 rats were killed.

2. Operation—Surgery was performed as in the method of Higgins and Anderson (9). Under ether anesthesia, the abdominal hair was cut at 4 × 3 cm range. From processus xiphoideus, the abdomen was opened about 3 cm by a midline incision. Partial hepatectomy referred to removal of the median and left lateral lobes of the liver. After bleeding had ceased, the blood residue in peritoneal cavity was cleaned and penicillin was injected. Then the abdomen was closed in two layers, and penicillin was again applied to the wound.

3. Chemical analyses—On the last day, after 4 h of fast, blood was taken from the tail vein and blood sugar was measured (10). Under ether anesthesia, whole blood was withdrawn from vena cava into a syringe; a part of it was used for measurement of hematocrit (11), then the remaining part was centrifuged to take serum for analyses of total protein (12), albumin (13), glutamate oxaloacetate transaminase (GOT) (14), glutamate pyruvate transaminase (GPT) (14), and triglycerides (TG) (15). Liver was taken and weighed and used for the measure-
ments of glycogen (16) and protein (17). Moisture content of the liver was also measured by weighing before and after 48 h drying at 110°C.

Experiment 2: 1. Animals and diets—Male rats of Wistar strain (Kyudo Company, Kumamoto) weighing about 250 g were used. After a 24 h fast, about 70% of liver was resected. The animals were maintained on experimental diets shown in Table 1 for 5 days from the next day of operation. All of the diets

Table 1. Compositions of diets (Experiment 2).

| Experiment | Group   | Crude protein (g/100 g) | Chain length (amino acids) | Diet (%) |
|------------|---------|-------------------------|---------------------------|----------|
| 2-A        | SP⁴     | 86.2                    |                           | 17.4     | 82.6     |
|            | SP A.A.⁵| 98.5                    |                           | 15.2     | 84.8     |
|            | SP pep-1⁶| 87.9                    | 3                         | 17.1     | 82.9     |
|            | SP pep-2⁶| 88.2                    | 3                         | 17.0     | 83.0     |
|            | SP pep-3⁶| 73.1                    | 8                         | 20.5     | 79.5     |
|            | SP pep-4²| 88.7                    | 5                         | 16.9     | 83.1     |
| 2-B        | E.W.⁷   | 82.4                    |                           | 18.2     | 81.8     |
|            | E.W. A.A.⁸| 98.7                    |                           | 15.2     | 84.8     |
|            | E.W. pep-1⁹| 87.5                    | 9                         | 17.1     | 82.9     |
|            | E.W. pep-2¹⁰| 79.8                    | 3                         | 18.8     | 81.2     |
| 2-C        | Casein  | 91.0                    |                           | 16.5     | 83.5     |
|            | Casein A.A.¹¹| 98.2                    |                           | 15.3     | 84.7     |
|            | Casein pep-1¹¹| 77.8                    | 4                         | 19.3     | 80.7     |
|            | Casein pep-2¹¹| 85.2                    | 5                         | 17.6     | 82.4     |

¹ Analyzed by Kjeldahl method. ² Peptide average chain length. ³ Contain 5% soybean oil, 5% mineral mixture, 2% cellulose, 1% vitamin mixture, and remaining parts were carbohydrates (α-starch:sucrose = 2:1). ⁴ Soybean protein. ⁵ Amino acid mixture (soybean protein pattern) consisted of (mg/g): alanine 41.5, arginine 73.1, asparagine 98.6, aspartic acid 17.0, cystine 12.8, glutamine 160.2, glutamic acid 35.4, glycine 40.5, histidine 23.7, isoleucine 45.4, leucine 77.1, lysine-HCl 75.4, methionine 11.9, phenylalanine 51.4, proline 52.4, serine 52.4, threonine 37.5, tryptophan 13.8, tyrosine 34.6, valine 45.4. ⁶ Enzymatically hydrolyzed soybean protein, donated by Fuji Oil Company, Osaka, Japan. ⁷ Egg white protein. ⁸ Amino acid mixture (egg white protein pattern) consisted of (mg/g): alanine 57.7, arginine 54.7, asparagine 99.7, cystine 29.3, glutamine 126.1, glycine 34.2, histidine 23.5, isoleucine 51.8, leucine 83.1, lysine-HCl 63.5, methionine 37.1, phenylalanine 56.7, proline 34.2, serine 60.6, threonine 42.0, tryptophan 14.7, tyrosine 37.1, valine 68.4, NH₄Cl 25.4. ⁹ Enzymatically hydrolyzed egg white protein, donated by Q.P. Corporation, Tokyo, Japan. ¹⁰ The amino acid mixture (casein pattern) consisted of (mg/g): alanine 26.7, arginine 32.0, asparagine 61.4, cystine 4.3, glutamine 186.8, glycine 16.0, histidine 26.7, isoleucine 48.0, leucine 82.7, lysine-HCl 88.4, methionine 26.7, phenylalanine 45.4, proline 100.1, serine 45.4, threonine 36.0, tryptophan 11.2, tyrosine 49.4, valine 58.7, NH₄Cl 54.0. ¹¹ Enzymatically hydrolyzed casein protein, donated by Morinaga Milk Industry, Tokyo, Japan.
contained 2.4% nitrogen, 5% soybean oil, 5% mineral mixture, 2% cellulose, and 1% vitamin mixture. The remaining part was carbohydrate (α-starch:sucrose = 2:1). The peptides were enzymatically hydrolyzed proteins and the average chain lengths are shown in Table 1. The amino acid mixtures were patterned after the amino acid compositions of each protein (18). On the 6th day post-operation, after 4 h of fast the rats were sacrificed and the same analyses were made as Experiment 1. All of the rats were kept in separate cages with a 12 h light-dark cycle. Food and water were renewed every morning, and the body weight, and amount of food intake were weighed.

2. Estimation of total liver weight—For calculating the recovery of liver, total and residual liver weights of hepatectomized rats were necessary. For this purpose, a preliminary study was done. Twenty-three rats weighing about 250 g were hepatectomized and the liver was resected. The resected liver (A), dying residual liver (B) (necrosis part which had no blood circulation due to the ligation of blood vessel), and living residual liver (C) (residual part which had blood circulation) were weighed. Total liver weight was the sum of A, B, and C (D). Average of resected liver weight (A), dying residual liver weight (B), and living residual liver weight (C) were 2.40±0.28, 0.06±0.05, 1.17±0.20 (g/100 g BW), respectively. The average of total liver weight (D) was 3.63±0.43 (g/100 g BW). Percentage of resected part of liver was 67.33±3.02% [(A+B)/D]. The ratio of resected liver to whole liver was 1.54 (D/A).

Table 2. Body weight, liver weight, and food intake (Experiment 1).

| Post-operation days | No. of rats | Body wt. (g) | Liver wt. (g) | Food intake (g) |
|---------------------|-------------|--------------|--------------|----------------|
| -1                  | 35¹ (5)²    | 252±5³       | 11.33±0.42   |                |
| 0                   | 30 (5)      | 221±6        | 7.89±0.64    |                |
|                     |             |              | 2.73±0.32    |                |
| 1                   | 25 (3)      | 206±6        | 3.41±0.14    |                |
| 2                   | 22 (3)      | 213±9        | 5.36±0.19    | 11.7±2.7       |
| 3                   | 19 (3)      | 223±8        | 7.26±0.11    | 15.8±1.3       |
| 4                   | 16 (3)      | 236±8        | 9.36±1.05    | 19.8±2.1       |
| 5                   | 13          | 250±9        | 23.7±1.5     |                |
| 6                   | 13 (3)      | 260±9        | 10.78±1.17   | 23.6±1.6       |
| 7                   | 10          | 274±10       | 24.9±3.2     |                |
| 8                   | 10 (3)      | 283±10       | 10.92±1.22   | 23.9±2.4       |
| 9                   | 7           | 291±12       | 23.3±4.1     |                |
| 10                  | 7           | 301±14       | 24.8±4.2     |                |
| 11                  | 7 (3)       | 311±14       | 13.25±0.49   | 24.2±3.0       |
| 12                  | 4           | 317±20       | 24.4±4.4     |                |
| 13                  | 4           | 325±21       | 24.4±4.4     |                |
| 14                  | 4           | 336±22       | 23.1±3.3     |                |
| 15                  | 4 (4)       | 345±23       | 14.51±2.66   | 23.0±3.1       |

¹Number of non-sacrificed rats. ²Number of sacrificed rats.³Values are M±SD.

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3. Liver recovery—On the day of operation, resected liver was weighed \( (E) \). Total liver weight \( (F) \) on the day of operation was calculated as \( 1.54E \). On the 6th day, rats were killed and the liver was weighed \( (G) \). The liver recovery was \( G/F \).

**Statistical analysis:** Statistical analysis was done by Student's \( t \)-test and Duncan's multiple-range test.

**Results. Experiment 1:** Table 2 shows the time course of body weight, liver weight, food intake before and after the hepatectomy. Body weight decreased about 45 g during the 2 starved days. After the operation, average liver weight was 11.33 g. After 24 h of fast, it became 7.89 g. By the operation it became 2.73 g, however, it increased to 3.41 g in spite of 24 h fast. After the operation liver weight increased to 9.39 g (about 2 g/day) linearly by the 4th day. Then the increasing rate fell to 0.5 g/day. On day 15 post-operation, liver weight was 14.51 g. Food intake increased from 12 to 24 g during the first 4 days, and remained constant at about 24 g throughout the experiment.

Table 3 shows the changes in liver composition and hematological values. The percentage of water of liver before operation was 71.5%. It fell to 69.1 and 66.5% on the 1st and 2nd day by fasting and operation. It increased to 73.8% rapidly the next day by the feeding, and maintained at the pre-operation level. Liver protein level rather increased by fasting but decreased 2-4 days after the operation and returned to the pre-operation level on the 8th day. After fasting, liver glycogen reduced to almost zero. It increased slowly and returned to pre-operation level at the 11th day.

Blood sugar reduced from 113 to 57 mg/dl by fasting and operation. When feeding was commenced it reverted to the original level on the 11th day after operation. Total protein decreased gradually after the operation until the 4th day. Albumin remained constant (3-4 g/dl) throughout the experimental period. GOT and GPT rose from 79 to 199 IU, 21 to 77 IU, respectively, by the operation. They returned to 69 and 32 IU on the 6th day.

**Experiment 2:** Table 4 shows body weight, food intake, food efficiency ratio (FER), and liver recovery. Growth and FER of casein pep-1 group were lower as compared to those of casein pep-2 and casein amino acid mixture groups. However, all the other diets showed the similar results with a few minor exceptions.

Table 5 shows the composition of liver and hematological values. Liver water level was similar in all the groups in each experiment except it was lower in casein amino acid group than in others in Experiment 2-C. Protein values were also similar in all the groups; however, the value in the SP group was a little lower than those of the other groups. Liver glycogen and all the hematological values were not significantly different among the dietary groups, except a few minor differences.

**Discussion.** The recovery of rats after hepatectomy has to be decided from various points. The important indicators are liver weight, body weight, liver glycogen \( (19) \), blood glucose \( (20, 21) \), serum albumin \( (22, 23) \), GOT, and GPT. The recovery-times to the pre-operation levels were 6 days for body weight, GOT,
Table 3. Composition of liver and hematological values (Experiment 1).

| Post-operation days | Liver composition | Hematological values |
|---------------------|-------------------|----------------------|
|                     | Water (%)         | Protein (%)          | Glycogen (%) | Glucose (mg/dl) | TP (g/dl) | Alb (g/dl) | GOT (IU) | CPT (IU) |
| −1 (5)¹             | 71.5±1.0²         | 16.2±0.8             | 3.0±2.1      | 113±9           | 5.54±0.32 | 3.26±0.41 | 78±14    | 32±7     |
| 0 (5)               | 69.1±0.8**        | 17.1±3.0             | 0.2±0.1*     | 71±5***         | 5.53±0.52 | 3.33±0.33 | 79±13    | 21±6*    |
| 1 (3)               | 66.5±1.0***       | 19.3±2.6*            | 0.1±0.1*     | 57±8***         | 5.23±0.16 | 3.78±0.16 | 199±23***| 77±31*   |
| 2 (3)               | 73.8±7.7          | 14.4±1.4*            | 1.3±0.4      | 79±9**          | 5.01±0.14*| 3.31±0.15 | 153±36** | 47±11*   |
| 3 (3)               | 74.1±0.5*         | 13.8±1.9*            | 0.3±0.3      | 65±17**         | 5.03±0.29*| 3.58±0.23 | 183±34** | 69±30*   |
| 4 (3)               | 72.2±2.0          | 14.4±0.6*            | 1.0±1.0      | 76±24*          | 5.27±0.68 | 3.02±0.12 | 118±21*  | 50±18    |
| 6 (3)               | 70.7±1.7          | 15.4±0.9             | 2.1±1.0      | 77±8**          | 6.39±0.18***| 3.70±0.06 | 69±8     | 32±4     |
| 8 (3)               | 69.5±1.2          | 16.0±1.1             | 1.5±1.4      | 90±8*           | 6.06±0.76 | 3.55±0.44 | 71±12    | 25±5     |
| 11 (3)              | 70.9±0.6          | 14.2±1.0*            | 3.9±0.7      | 112±8           | 6.94±0.49**| 3.71±0.10 | 74±15    | 37±7     |
| 15 (4)              | 70.4±1.9          | 15.6±1.3             | 4.1±0.7      | 99±9            | 6.99±0.38***| 3.90±0.17*| 107±21   | 50±5*    |

¹Number of sacrificed rats. ²Values are M±SD. *, **, ***Significantly different from the value of pre-operative day by Student's t-test at p<0.05, p<0.01, and p<0.001, respectively.
Table 4. Body weight gain, food intake, FER, and liver recovery (Experiment 2). 1

| Experiment | Group   | n  | BW gain (g/day) | Food intake (g/day) | FER 3 | Liver recovery (%) |
|------------|---------|----|----------------|--------------------|-------|--------------------|
|            |         |    |                |                    |       |                    |
| 2-A        | SP      | 5  | 4.7±0.8        | 14.3±1.5           | 0.32±0.03 ab | 69.3±4.5 |
|            | SP A.A. | 4  | 6.3±1.7        | 16.4±1.6           | 0.43±0.07 a  | 69.8±1.2 |
|            | SP pep-1| 6  | 4.2±0.6        | 15.0±0.8           | 0.27±0.03 b  | 65.0±4.6 |
|            | SP pep-2| 6  | 6.0±0.7        | 17.1±0.3           | 0.35±0.03 ab | 69.2±3.0 |
|            | SP pep-3| 6  | 6.2±1.1        | 16.7±0.8           | 0.36±0.05 ab | 66.9±6.0 |
|            | SP pep-4| 5  | 4.5±0.8        | 15.6±1.5           | 0.28±0.03 b  | 67.2±3.0 |
| 2-B        | E.W.    | 7  | 9.2±0.8        | 18.7±0.6 a, 2      | 0.49±0.04 a  | 85.8±3.8 |
|            | E.W. A.A.| 7  | 8.7±0.5        | 21.3±0.6 b         | 0.41±0.02 ab | 92.1±3.3 |
|            | E.W. pep-1| 6  | 7.3±0.9        | 19.4±0.5 a         | 0.38±0.04 b  | 87.8±6.4 |
|            | E.W. pep-2| 6  | 7.3±0.5        | 17.7±0.6 a         | 0.41±0.02 ab | 88.0±5.9 |
| 2-C        | Casein  | 12 | 8.6±0.4 ab     | 16.8±0.9 a         | 0.47±0.04 a  | 87.0±4.0 b |
|            | Casein A.A.| 8  | 9.4±0.4 a     | 19.5±0.4 ab        | 0.48±0.02 b  | 106.4±5.1 b |
|            | Casein pep-1| 12 | 7.6±0.5 b     | 20.0±0.8 b         | 0.40±0.03   | 94.1±5.2 ab |
|            | Casein pep-2| 12 | 9.5±0.5 b     | 20.2±1.1 b         | 0.50±0.05   | 91.2±1.7 * |

1 Values are M±SE. 2 Means with different superscript letters in each experiment are significantly different by Duncan's multiple-range test (p < 0.05). 3 FER, food efficiency ratio (body weight gain/food intake).

and GPT, and 11 days for liver weight, liver glycogen, and blood glucose, respectively. Other indicators such as liver water and protein, serum total protein and albumin were rather similar to the pre-operation levels throughout the experimental period. Therefore we inferred that 10 days seemed appropriate for the rats to recover from such stress.

The comparative effects of the various diets may be evident during the period of recovery, as the indicators tend to be similar among the dietary groups after total recovery. The recovery ratios on the 6th day post-operation against the pre-operation levels were 103% for body weight, 95% for liver weight, 95% for liver protein, 70% for liver glycogen, 115% for serum total protein, 68% for blood glucose, 88% for GOT, and 100% for GPT. From these results of Experiment 1, we estimated the 6th day after the stress to be suitable for the comparison of the recovery among various dietary groups in Experiment 2.

Although many researchers have reported the superiority of peptides to amino acid mixture or proteins in normal and under surgical stress, especially stress of digestive organs, in animals and men, we could not observe such benefit of peptides in our studies (3). In the present experiment we studied 3 types of proteins, 3 types of amino acid mixtures, and 8 types of peptides produced from these proteins by enzymatic hydrolysis but could not observe any superiority of peptides to protein and amino acids on the recovery of rats from 70% hepatectomy. On the contrary, one of the peptides produced from casein (casein pep-1) was rather inferior to amino acid mixture in the growth and food efficiency ratio. We did histological examination (data not shown) but no difference was observed among the different
Table 5. Composition of liver and hematological values (Experiment 2).  

| Group          | n | Liver composition | Hematological values |
|----------------|---|-------------------|----------------------|
|                |   | Water (%)         | Protein (%)          | Glycogen (%)         | Hematocrit (%) | Glucose (mg/dl) | TP (g/dl) | Alb (g/dl) | GOT (IU) | GPT (IU) | TG (mg/dl) |
| Exp. 2-A       |   |                   |                      |                      |               |               |          |            |          |           |            |
| SP             | 5 | 72.3 ± 1.4        | 16.4 ± 0.6          | 3.0 ± 0.7           | 40.6 ± 1.2    | 174 ± 14      | 4.2 ± 0.1 | 2.9 ± 0.1 | 147.4 ± 32.5 | 42.0 ± 5.9 | 30 ± 4 |
| SP A.A.        | 4 | 70.1 ± 1.0        | 18.8 ± 0.6          | 2.2 ± 0.4           | 40.8 ± 2.5    | 149 ± 16      | 4.4 ± 0.2 | 3.2 ± 0.2 | 161.1 ± 66.9 | 68.0 ± 26.3 | 37 ± 5 |
| SP pep-1       | 6 | 71.9 ± 0.6        | 18.8 ± 0.5          | 2.7 ± 0.4           | 41.8 ± 0.7    | 150 ± 12      | 4.4 ± 0.1 | 3.1 ± 0.1 | 169.0 ± 46.2 | 58.8 ± 13.1 | 29 ± 3 |
| SP pep-2       | 6 | 71.7 ± 1.0        | 18.7 ± 0.5          | 3.3 ± 0.6           | 42.8 ± 0.4    | 155 ± 13      | 4.5 ± 0.1 | 3.2 ± 0.1 | 194.8 ± 46.1 | 79.8 ± 14.6 | 30 ± 3 |
| SP pep-3       | 6 | 72.2 ± 0.7        | 18.8 ± 0.7          | 3.8 ± 0.7           | 41.8 ± 1.3    | 161 ± 11      | 4.5 ± 0.1 | 3.1 ± 0.1 | 147.7 ± 21.4 | 58.3 ± 8.6 | 33 ± 4 |
| SP pep-4       | 5 | 71.7 ± 1.1        | 20.2 ± 0.6          | 3.6 ± 0.4           | 42.4 ± 1.2    | 165 ± 14      | 4.4 ± 0.2 | 3.1 ± 0.2 | 214.5 ± 44.5 | 96.5 ± 20.1 | 34 ± 1 |
| Exp. 2-B       |   |                   |                      |                      |               |               |          |            |          |           |            |
| E.W.           | 7 | 71.8 ± 1.4        | 18.6 ± 0.6          | 3.7 ± 0.3           | 40.6 ± 1.1    | 192 ± 16      | 4.4 ± 0.1 | 3.1 ± 0.1 | 292.2 ± 142.9 | 55.3 ± 52.7 | 40 ± 4 |
| E.W. A.A.      | 7 | 71.6 ± 0.4        | 20.0 ± 0.6          | 2.9 ± 0.2           | 39.9 ± 0.8    | 193 ± 15      | 4.6 ± 0.1 | 3.3 ± 0.1 | 185.0 ± 144.2 | 55.8 ± 42.3 | 36 ± 3 |
| E.W. pep-1     | 6 | 72.5 ± 0.8        | 19.1 ± 0.7          | 4.4 ± 0.9           | 39.2 ± 1.5    | 175 ± 12      | 4.4 ± 0.1 | 3.2 ± 0.1 | 133.6 ± 45.8 | 42.8 ± 15.2 | 37 ± 6 |
| E.W. pep-2     | 6 | 73.7 ± 1.3        | 17.9 ± 0.6          | 2.3 ± 0.5           | 40.6 ± 1.1    | 195 ± 26      | 4.4 ± 0.1 | 3.2 ± 0.1 | 105.8 ± 42.0 | 34.0 ± 14.5 | 48 ± 7 |
| Exp. 2-C       |   |                   |                      |                      |               |               |          |            |          |           |            |
| Casein         | 12| 71.6 ± 0.4        | 20.3 ± 0.4          | 2.9 ± 0.7           | 37.3 ± 1.0    | 127 ± 10b     | 4.6 ± 0.1 | 2.4 ± 0.3 | 125.8 ± 59.7 | 43.7 ± 14.6 | 53 ± 8 |
| Casein A.A.    | 8 | 67.3 ± 1.0        | 20.1 ± 0.5          | 2.6 ± 0.3           | 37.0 ± 0.5    | 115 ± 4a      | 4.6 ± 0.1 | 1.8 ± 0.1 | 141.6 ± 12.6 | 56.4 ± 9.4 | 20 ± 2 |
| Casein pep-1   | 12| 70.8 ± 0.5        | 19.8 ± 0.6          | 3.0 ± 0.5           | 38.0 ± 0.9    | 143 ± 9a      | 4.5 ± 0.1 | 2.3 ± 0.3 | 135.5 ± 28.6 | 51.1 ± 21.9 | 46 ± 8 |
| Casein pep-2   | 12| 71.2 ± 0.6        | 20.1 ± 0.6          | 3.2 ± 0.7           | 38.8 ± 0.8    | 145 ± 8b      | 4.5 ± 0.1 | 2.3 ± 0.3 | 143.4 ± 39.2 | 45.7 ± 19.4 | 43 ± 8 |

1 Values are M ± SE. 2 Means with different superscripts letters in each experiment are significantly different by Duncan's multiple-range test (p < 0.05).
nitrogen sources. Therefore we are inclined to disagree with other workers regarding effective utilization of peptides in comparison to amino acid mixtures and proteins.

From these reports, we may be able to conclude that some specific peptides may be superior to amino acid mixtures or proteins but, in general, relative nutritional value of peptides is similar to other forms of nitrogen. Therefore the superiority of peptides should not be claimed without careful evaluations.

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