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Nicotinic Acid, Lysine, Tryptophan and Threonine as Supplements to High-Protein Corn

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ABSTRACT

This sample of corn contained approximately 16% of protein and made up from 92.8 to 94.5% of the experimental diet. The other components were threonine, minerals, and vitamins, with the exception of nicotinic acid. The experimental diets contained added nicotinic acid, lysine and tryptophan, singly and in various combinations. There were 11 different rations, with 6 rats on each. Special precautions were taken to secure accurate records of food consumption. Each animal was analyzed at the end of the 4-week experimental period. Control animals were analyzed at the beginning of the experimental period and it was possible to make a number of calculations.

The imbalance of amino acids in high-protein corn is more serious than it is in low-protein corn. The sample used contained 2.1 mg. % of nicotinic acid; that amount was insufficient. When 5 mg. % was added to the diet there was a marked increase in the amount of food consumed by the experimental animals. There was a corresponding increase in the rate of gain in body weight and in each constituent of the body.

When lysine alone was added to the basal diet there was a moderate increase in the amount of food consumed and in the number of calories gained. There was no increase in the amount of fat gained. There was a large increase in the amount of protein and of water gained. The diet was markedly improved by all criteria when tryptophan and lysine were included in the diet simultaneously.

There was no additional improvement when nicotinic acid was included with the combination of lysine and tryptophan.

When tryptophan alone was added to the basal diet none of the responses was statistically significant. However, there were consistent increases in the amount of food consumed, in the rate of gain in body weight, and in each tissue constituent.

If the diet contained nicotinic acid, there was no response to the addition of tryptophan. This amino acid could be regarded as the second limiting amino acid.

No evidence was obtained that the mixture of proteins in corn is deficient in threonine.

High-protein corn was estimated to contain 30% of the optimum amount of lysine and 40% of the optimum amount of tryptophan.

There are important differences in the responses when lysine and nicotinic acid are added to low-protein and to high-protein corn.

As a source of nitrogen for the rat, casein is vastly superior to the mixture of proteins in high-protein corn, even through the latter is supplemented with lysine and tryptophan.

CONTENTS

This bulletin reports on Department of Agricultural Chemistry research project 212, Food Conservation

Nicotinic Acid, Lysine, Tryptophan and Threonine as Supplements to High-Protein Corn

Two preceding publications (1, 2) should be consulted for the historical background of this study, and for most of the procedural description. The object of this investigation was to obtain additional information on high-protein corn as a source of nicotinic acid, lysine, tryptophan and threonine.

MATERIALS AND METHODS

The experimental animals were rats of the Wistar Institute strain. The length of the experimental period was 28 days. Most of the previous workers used corn that contained only an average, or low, percentage of protein. It is possible, however, by breeding and liberal application of nitrogen to the soil to obtain corn that contains twice as much protein as does the grain in common use.

The sample*used in this investigation was white and was grown in Illinois. It contained 2.1 mg. % of nicotinic acid and 16.1% of protein (N 6.25), made up of 6% zein and 10.1% of other proteins. Each diet contained 4% of a mineral mixture, 1% of calcium carbonate, 0.5% of soybean oil and the vitamin mixture described in Table 1 of Missouri Research Bulletin 678 (2).

Amounts of the variable constituents are shown in the tables that describe the results. The crude protein content was relatively constant among the 11 rations used. It varied from 15.2% on the basal diet, No. I, to 16.5% in Diets V and IX, which contained all three of the amino acid supplements.

A positive control diet, No. XI, contained no corn, but this constituent was replaced by 17.7 gm. of casein, 0.2 gm. DL-methionine, 76.6 gm. of corn starch and 5 mg. of nicotinic acid. The vitamin constituents were the same as in the corn rations.

Basic data accumulated during this investigation are summarized in Tables 6, 7 and 8 of the appendix.

RESULTS

Nicotinic Acid.

It has been observed that a deficiency of nicotinic acid may be precipitated by an imbalance in the amino acid intake; a portion of our data on this point is shown in Table 1.

*Supplied by L. F. Bauman, Department of Agronomy, University of Illinois, July, 1950. Marked: 3437 M-2-N.

TABLE 1--CORN AS A SOURCE OF NICOTINIC ACID

Comparison	A			B			C			D	
Ration	II		VI	III		VII	IV		VIII	V	IX
Corn, %	94.0		94.0	93.8		93.8	93.0		93.0	92.8	92.8
DL-Threonine[1], %	0.5		0.5	0.5		0.5	0.5		0.5	0.5	0.5
DL-Tryptophan[2], %	----		----	0.2		0.2	----		----	0.2	0.2
L-Lysine.HCl[3], %	----		----	----		----	1		1	1	1
Nicotinic acid, mg. %	----		5	----		5	----		5	----	5
Observations on the animals.											
Food consumed, gm.	157	*	209	169	*	209	175	**	251	299	286
Protein consumed, gm.	24.1	*	31.9	26.2	*	32.3	28.7	**	41.1	49.5	47.3
Gain in weight, gm.	27.3		38.4	31.9		39.7	39.1	**	63.4	94.9	84.9
Gain in water, gm.	15.5		21.9	18.2		22.0	24.2	**	37.3	56.2	52.3
Gain in protein, gm.	3.7		5.5	4.3		5.5	6.7	**	10.6	17.5	15.6
Gain in fat, gm.	6.6		9.2	7.6		10.1	6.2	**	12.9	16.9	13.6
Gain in ash, gm.	1.09		1.37	1.15		1.44	1.43	**	2.13	3.01	2.81
Gain in calories	84		118	97		127	97	**	182	260	217
Gain in weight/gm. food consumed, gm.	0.17		0.18	0.19		0.19	0.21	*	0.25	0.32	0.3
Gain in weight/gm. protein consumed, gm.	1.1		1.2	1.2		1.2	1.4	*	1.5	1.9	1.8
Gain in protein/gm. protein consumed, gm.	0.15		0.17	0.16		0.17	0.23	**	0.26	0.35	0.33
Gain in calories/gm. food consumed	0.53		0.55	0.57		0.59	0.49	**	0.71	0.87	0.75
Gain in calories/gm. protein consumed	3.5		3.7	3.7		3.9	3.4	**	4.4	5.3	4.6
Fat gained ÷ protein gained	1.8		1.7	1.8		1.8	0.9	*	1.2	1.0	0.9

Statistical significance $*P < 0.05$ $**P < 0.01$

[1] Purchased from Distillation Products Industries, Rochester, N. Y.

[2] Courtesy of the Dow Chemical Co., Midland, Mich.

[3] Courtesy of Dr. J. Waddell, E. I. du Pont de Nemours and Co., New Brunswick, N. J.

When nicotinic acid was added to the basal ration, No. II in comparison A, there was definite improvement in the response of the rats. The increase in food consumption reached statistical significance at the 5% level. All of the gains were increased but the differences were not mathematically significant. Presumably this failure was due to the small number of experimental animals.

Ration III in comparison B contained 0.2% of added DL-tryptophan; when it was supplemented with nicotinic acid the food intake was significantly increased, but to a lesser degree than in comparison A. If the animals on Rations II and III are combined and compared with the combination of Rations VI and VII, the statistical significance of the data is increased. The probability that the differences are due to chance becomes less than 1% for food consumed and less than 5% for gain in weight. The control ration in comparison C contained 1% of L-lysine; when it was supplemented with nicotinic acid the difference in every item compared was statistically significant, usually at a level of 1%. In comparison D the control ration contained both added tryptophan and added lysine and in this case there was no response to added nicotinic acid.

It is evident then that under the experimental conditions, the basal ration is deficient in nicotinic acid. It is still deficient when either tryptophan alone in the amount specified, or lysine alone is added to this ration. However, when these amino acids are added simultaneously, as in Ration V, there is no response to the addition of nicotinic acid.

It should be noted that there was a sharp contrast between high-and low-protein corn in their effect on the nicotinic acid requirement. There was seldom any response when this vitamin was added to low-protein corn (2).

Lysine

To show more clearly the effect of adding lysine to the proteins of corn, our data are rearranged in Table 2.

There was a definite response in food consumption and in gain in weight when lysine was added to the basal diet, No. II, comparison A, but the number of animals was too small to show statistical significance. However, some of the criteria did reach statistical significance. These included the gain in protein, and water, the gain in protein per unit of protein consumed, and the ratio of gain in fat to gain in protein. The gain in weight per unit of food consumed barely failed to reach a significant level. It is evident that the chief effect of the added lysine was to increase the gains in protein, along with the water that accompanies protein. This is the result that would be expected if lysine was the first limiting amino acid.

When lysine was included in rations that already contained either added nicotinic acid or added tryptophan, as in comparisons B, C and D, practically all differences in response, by all criteria, reach a significant magnitude. Both the increase in food consumption and the increase in food efficiency testify to the limiting effect of the deficiency of lysine in the proteins of corn.

TABLE 2--CORN PROTEINS AS A SOURCE OF LYSINE

Comparison	A			B			C			D		
Ration	II		IV	VI		VIII	III		V	VII		IX
Corn, %	94.0		93.0	94.0		93.0	93.8		92.8	93.8		92.8
DL-Threonine, %	0.5		0.5	0.5		0.5	0.5		0.5	0.5		0.5
Nicotinic acid, mg. %	----		----	5		5	----		----	5		5
DL-Tryptophan, %	----		----	----		----	0.2		0.2	0.2		0.2
L-Lysine.HCl, %	----		1	----		1	----		1	----		1
Observations on the animals.												
Food consumed, gm.	157		175	209	*	251	169	**	299	209	**	286
Protein consumed, gm.	24.1		28.7	31.9	*	41.1	26.2	**	49.5	32.3	**	47.3
Gain in weight, gm.	27.3		39.1	38.4	**	63.4	31.9	**	94.8	39.7	**	84.9
Gain in water, gm.	15.5	*	24.2	21.9	**	37.3	18.2	**	56.2	22.0	**	52.3
Gain in protein, gm.	3.7	*	6.7	5.5	**	10.6	4.3	**	17.5	5.5	**	15.6
Gain in fat, gm.	6.6		6.2	9.2		12.9	7.6	**	16.9	10.1		13.6
Gain in ash, gm.	1.09		1.43	1.37	**	2.13	1.15	**	3.01	1.44	**	2.81
Gain in calories	84		97	118	*	182	97	**	260	127	**	217
Gain in weight/gm. food consumed, gm.	0.17		0.21	0.18	**	0.25	0.19	**	0.32	0.19	**	0.30
Gain in weight/gm. protein consumed, gm.	1.1		1.4	1.2	**	1.5	1.2	**	1.9	1.2	**	1.8
Gain in protein/gm. protein consumed, gm.	0.15	**	0.23	0.17	**	0.26	0.16	**	0.35	0.17	**	0.33
Gain in calories/gm. food consumed	0.53		0.49	0.55	*	0.71	0.57	**	0.87	0.59	*	0.75
Gain in calories/gm. protein consumed	3.5		3.4	3.7	*	4.4	3.7	**	5.3	3.9		4.6
Fat gained ÷ protein gained	1.8	**	0.9	1.7	**	1.2	1.8	**	1.0	1.8	**	0.9

Statistical significance *$P < 0.05$ **$P < 0.01$

A study of the results on Rations IV and VI illustrates the importance of an analysis of the experimental animals. The gains in weight on these two rations were almost identical. However, the rats on lysine made the larger gains in protein and water, and the smaller gain in fat and calories. They also ate less food. Gains in weight alone may be misleading.

Tryptophan

Our studies on the deficiency of tryptophan in corn protein are illustrated by another arrangement of the data, shown in Table 3.

When 0.2% of tryptophan was added to the basal diet, as in comparison A, there was a slight but consistent increase in the amount of food consumed, in the rate of gain in weight, and in all tissue constituents. It was felt that if the number of experimental animals could have been greatly increased the differences would have attained statistical significance. Such a result would be expected, inasmuch as Ration II was deficient in nicotinic acid. However, the tryptophan would be expected to bring about a much more marked response than actually occurred. This point will be considered again.

In comparison B, the control diet contained nicotinic acid. When tryptophan was added to this diet there was no response. This is understandable because lysine was the first limiting amino acid and the tryptophan was not needed as a precursor of nicotinic acid. Comparison C shows that when tryptophan was added to a ration that contained lysine, the diet was vastly improved by practically every criterion. When added to a ration that contains both nicotinic acid and lysine (comparison D) there is less room for increased responses. Even then, however, there was notable improvement by six criteria, and a few of the others narrowly missed statistical significance. High-protein corn is deficient in tryptophan, but the deficiency in lysine is slightly more critical.

Threonine

It has been suggested that threonine might be on the borderline of deficiency in the proteins of corn and it was included in most of the rations as an insurance measure. Our attempt to determine whether or not this inclusion was helpful is described in Table 4.

Comparisons A and B give no indication from any point of view that threonine is a limiting factor in the protein of corn. As a matter of fact the highest mean weight of all those we obtained was observed on Ration X, which contained no added threonine.

Miscellaneous

Our data permit a few comparisons not yet mentioned that deserve additional emphasis. These are brought together in Table 5.

There has been some discussion as to whether lysine or tryptophan is the first limiting amino acid in the proteins of corn. Our data pertinent to this point

TABLE 3--CORN PROTEINS AS A SOURCE OF TRYPTOPHAN

Comparison	A		B		C			D		
Ration	II	III	VI	VII	IV		V	VIII		IX
Corn, %	94.0	93.8	94.0	93.8	93.0		92.8	93.0		92.8
DL-Threonine, %	0.5	0.5	0.5	0.5	0.5		0.5	0.5		0.5
Nicotinic acid, mg. %	----	----	5	5	----		----	5		5
L-Lysine-HCl, %	----	----	----	----	1		1	1		1
DL-Tryptophan	----	0.2	----	0.2	----		0.2	----		0.2
Observations on the animals.										
Food consumed, gm.	157	169	209	209	175	**	299	251		286
Protein consumed, gm.	24.1	26.2	31.9	32.3	28.7	**	49.5	41.1	*	47.3
Gain in weight, gm.	27.3	31.9	38.4	39.7	39.1	**	94.9	63.4	**	84.9
Gain in water, gm.	15.5	18.2	21.9	22.0	24.2	**	56.2	37.3	**	52.3
Gain in protein, gm.	3.7	4.3	5.5	5.5	6.7	**	17.5	10.7	**	15.6
Gain in fat, gm.	6.6	7.6	9.2	10.1	6.2	**	16.9	12.9		13.6
Gain in ash, gm.	1.09	1.15	1.37	1.44	1.43	**	3.01	2.13	**	2.81
Gain in calories	84	97	118	127	97	**	260	182		217
Gain in weight/gm. food consumed, gm.	0.17	0.19	0.18	0.19	0.21	**	0.32	0.25	**	0.30
Gain in weight/gm. protein consumed, gm.	1.1	1.2	1.2	1.2	1.4	**	1.9	1.5		1.8
Gain in protein/gm. protein consumed, gm.	0.15	0.16	0.17	0.19	0.23	**	0.35	0.26	**	0.33
Gain in calories/gm. food consumed	0.53	0.57	0.55	0.59	0.49	**	0.87	0.71		0.75
Gain in calories/gm. protein consumed	3.5	3.7	3.7	3.9	3.4	**	5.3	4.4		4.6
Fat gained ÷ protein gained	1.8	1.8	1.7	1.8	0.9		1.0	1.2		0.19

Statistical significance *P < 0.05 **P < 0.01

TABLE 4--CORN PROTEINS, AS A SOURCE OF THREONINE

Comparison	A		B	
Ration	I	II	X	IX
Corn, %	94.5	94.0	93.3	92.8
Nicotinic acid, mg. %	----	----	5	5
L-Lysine-HCl, %	----	----	1	1
DL-Tryptophan, %	----	----	0.2	0.2
DL-Threonine, %	----	0.5	----	0.5
Observations on the animals				
Food consumed, gm.	164	157	314	286
Protein consumed, gm.	25.0	24.1	51.8	47.3
Gain in weight, gm.	29.0	27.3	89.9	84.9
Gain in water, gm.	15.8	15.5	53.9	52.3
Gain in protein, gm.	3.8	3.7	16.0	15.6
Gain in fat, gm.	7.7	6.6	14.9	13.6
Gain in ash, gm.	1.1	1.1	2.7	2.8
Gain in calories	95	84	234	217
Gain in weight/gm. food consumed, gm.	0.18	0.17	0.29	0.30
Gain in weight/gm. protein consumed, gm.	1.2	1.1	1.8	1.8
Gain in protein/gm. protein consumed, gm.	0.15	0.15	0.31	0.33
Gain in calories/gm. food consumed	0.57	0.53	0.74	0.75
Gain in calories/gm. protein consumed	3.8	3.5	4.6	4.6
Fat gained ÷ protein gained	2.1	1.8	0.9	0.9

TABLE 5--MISCELLANEOUS COMPARISONS

Comparison	A		B		C		D		E	
Ration	IV	III	IV	VI	III	VI	V	VIII	X	XI
Casein, %	----	----	----	----	----	----	----	----	----	17.7
Corn, %	93.0	93.8	93.0	94.0	93.8	94.0	92.8	93.0	93.3	----
DL-Threonine, %	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	----	----
DL-Tryptophan, %	----	0.2	----	----	0.2	----	0.2	----	0.2	----
L-Lysine-HCl, %	1	----	1	----	----	----	1.0	1.0	1.0	----
Nicotinic acid, mg. %	----	----	----	5	----	5	----	5	5	----
Observations on the animals.										
Food consumed, gm.	175	169	175	209	169 *	209	299 **	251	314	317
Protein consumed, gm.	28.7	26.2	28.7	31.9	26.2	31.9	49.5 **	41.1	51.2	48.6
Gain in weight, gm.	39.1	31.9	39.1	38.4	31.9	38.4	94.9 **	63.4	89.9 **	117.4
Gain in water, gm.	24.2	18.2	24.2	21.9	18.2	21.9	56.2 **	37.3	53.9 **	72.7
Gain in protein, gm.	6.7	4.3	6.7	5.5	4.3	5.5	17.5 **	10.6	16.0 **	23.1
Gain in fat, gm.	6.2	7.6	6.2	9.2	7.6	9.2	16.9	12.9	14.9	17.6
Gain in ash, gm.	1.43	1.15	1.43	1.37	1.15	1.37	3.01 **	2.13	2.73 **	3.64
Gain in calories	97	97	97	118	97	118	260 **	182	234 *	299
Gain in weight/gm. food consumed, gm.	0.21	0.19	0.21	0.18	0.19	0.18	0.32 **	0.25	0.29 **	0.37
Gain in weight/gm. protein consumed, gm.	1.4	1.2	1.4	1.2	1.2	1.2	1.9 **	1.5	1.8 **	2.4
Gain in protein/gm. protein consumed, gm.	0.23 **	0.16	0.23 **	0.17	0.16	0.17	0.35 **	0.26	0.31 **	0.48
Gain in calories/gm. food consumed	0.49	0.57	0.49	0.55	0.57	0.55	0.87 *	0.71	0.74 **	0.94
Gain in calories/gm. protein consumed	3.4	3.7	3.4	3.7	3.7	3.7	5.3	4.4	4.5 **	6.2
Fat gained ÷ protein gained	0.9 **	1.8	0.9 **	1.7	1.8	1.7	1.0	1.2	0.9	0.8

Statistical significance $*P < 0.05$ $**P < 0.01$

are in comparison A. In most cases larger numbers would be required for statistical significance, but in practically every comparison the diet that contains added lysine is slightly superior to the one that contains added tryptophan. In two items the differences are highly significant, the efficiency of gains in protein and the ratio of fat to protein retained. These differences show that lysine is the first limiting amino acid in this sample of corn, the result one would expect from the amino acid content of high-protein corn.

According to our assays the proteins in this sample contained 2% of lysine and 0.6% of tryptophan. According to the data in Table 1 of Research Bulletin 678 (2), this is less than 30% of the optimum amount of lysine[1] and 40% of the optimum amount of tryptophan.** The difference in degree of deficiency was not large but lysine would be the first limiting factor. The proteins of high-protein corn were more severely deficient in lysine and tryptophan, then, than was the mixture in low-protein corn. However, as shown in an earlier publication (1), the increase in the amount of protein in high-protein corn more than compensated for the decrease in percentage of these amino acids. In our experience, high-protein corn is superior to low-protein corn, even for the monogastric animal. It should be mentioned though that Reussner and Thiessen (3) found no significant difference in the biological value of the protein mixture of low- and high-protein corn. However, the differences in protein content were less extreme in their samples than in ours.

As is shown in comparison B the gain in weight was practically the same when the basal diet was supplemented with nicotinic acid as when it was supplemented with lysine. This result was unexpected but the more important facts are clear. When the supply of nicotinic acid was increased the animals consumed more food. When the basal diet was supplemented with lysine the increase in food consumption was smaller and the gain in fat was smaller, but the gain in protein was slightly larger. The gain in protein per unit of protein consumed was significantly larger and the ratio of fat stored to protein stored was significantly smaller. Since the storage of protein on Ration VI was limited by the deficiency of lysine, more of the food energy was retained as fat. According to comparison B, lysine is superior to nicotinic acid as a supplement to the basal diet.

Comparison C shows that in some respects the diet was improved more by the addition of nicotinic acid than by the addition of tryptophan. It is noteworthy that when the vitamin was included in the diet the consumption of food was significantly higher than when the amino acid was included. This increase alone would explain the superiority of Ration VI. The gains in weight and in tissue constituents were also higher in Group VI than in Group III, but these differences did not reach statistical significance, presumably because there were too few experimental animals.

The inferiority of tryptophan to nicotinic acid as a supplement to the basal diet is difficult to explain. Presumably tryptophan is a precursor of nicotinic acid,

**Assayed by Laura M. Flynn

and animals would respond to the amino acid in the same way that they do to the vitamin. They did not do so, however, when Ration II was the basal diet. It is supposed that the ineffectiveness of tryptophan was due to some unfavorable quantitative interrelations. It is worthy of note that when lysine was included in the diet, contrast D, tryptophan was much superior to nicotinic acid.

Biological Value of Supplemented Corn Proteins

Diet X was one of the better corn rations; in comparison E it is compared with Ration XI, which contains casein as the source of protein. There was no difference in the amount of food consumed on these two rations, but by practically every other criterion, casein was vastly superior to the protein of corn, even when the latter was supplemented with lysine and tryptophan. When lysine and tryptophan are added to the corn ration, some other amino acid becomes a limiting factor.

The responses of the rats reported in this bulletin and in Research Bulletin 678 (2) are significantly different in some respects. Thus when nicotinic acid was added to high-protein corn the effect was much more marked than when added to low-protein corn. It is known that the amino acids of corn proteins are present in unsuitable ratios. One would suppose then that the damage due to this imbalance increases in some proportion to the increase in the amount of dietary protein, but especially to the increase in the amount of zein. The best example of this marked effect is found in some of the parallel data on the two types of corn. Thus in Table 1, comparison C, nicotinic acid was included in a ration that already contained added lysine. The response was highly significant. A similar comparison with low-protein corn was shown in Research Bulletin 678 (2), Table 2, comparison 3. The effect, if any, was slight. In Table 2 of this bulletin, comparisons A and B show the effects of adding lysine to a corn ration. The effects of the addition show a considerable degree of significance. A similar study on low-protein corn was described in Research Bulletin 678 (2). The effects of the addition of lysine to low-protein corn had a lower degree of significance. This difference in response is understandable, for zein makes up 25% of the total protein in low-protein corn and 37% in high-protein corn.

SUMMARY

The nutritional value of high-protein corn has been investigated. Of the essential amino acids in this sample, the deficiency in lysine was the most serious. Tryptophan was only slightly less deficient. The third limiting amino was not identified, but was not threonine.

When nicotinic acid or lysine was added singly to the basal diet there was an increase in the amount of food consumed; the gains in body weight were approximately the same. The gains in protein and water were larger on lysine than on nicotinic acid, but the gains in fat and calories were less.

When tryptophan was added to the basal diet there was a slight increase in the amount of food consumed and in the amount stored of each body constituent. The increases were below statistical significance. A combination of tryptophan and nicotinic acid was not superior to nicotinic acid alone. A combination of tryptophan and lysine was much superior to lysine alone and was not improved by a further addition of nicotinic acid.

As a source of protein, casein is vastly superior to corn, even when the latter is supplemented with lysine and tryptophan.

LITERATURE CITED

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APPENDIX

TABLE 6--WEIGHTS OF ANIMALS

Ration Supplements Added to Basal Diet	Weights of Animals: Live, Initial	Live, Final	Carcass, Initial[1]	Carcass, Final
	gm.	gm.	gm.	gm.
I - T[2] omitted	35.8	66.3	31.7	60.7
II - None	33.9	62.0	29.4	56.7
III - Tr.[3] 0.2	32.2	64.6	27.2	59.1
IV - L[4] 1	34.0	74.8	29.0	68.1
V - Tr. 0.2, L 1	34.0	132.9	29.3	124.2
VI - N[5]	33.0	71.8	28.4	66.8
VII - Tr. 0.2, N	34.0	75.2	29.7	69.4
VIII - L 1, N	33.8	101.2	29.1	92.5
IX - Tr. 0.2, L 1, N	33.7	122.9	29.2	114.1
X - T omitted Tr. 0.2, L 1, N	32.1	125.9	27.3	117.3
XI - T omitted M[6] 0.2, N	33.5	152.1	28.4	145.8
Initial Controls	33.0		30.7	

[1] The initial fasted live weights were 0.8 gm. more than the initial carcass weights.
[2] T - Threonine, %
[3] Tr - DL-tryptophan, %
[4] L - DL-lysine monohydrochloride, %
[5] N - Nicotinic acid, 5 mg. %
[6] M - DL-methionine, %

TABLE 7--AVERAGE COMPOSITION OF ANIMALS, INITIAL

Group	Water	Protein	Fat	Ash
	gm.	gm.	gm.	gm.
I	22.75	6.16	1.58	1.11
II	21.12	5.72	1.47	1.03
III	19.53	5.29	1.36	0.95
IV	21.05	5.69	1.46	1.03
V	21.05	5.70	1.46	1.03
VI	20.38	5.52	1.42	0.99
VII	21.33	5.77	1.48	1.04
VIII	20.93	5.66	1.46	1.02
IX	20.97	5.68	1.46	1.02
X	19.62	5.31	1.37	0.96
XI	20.41	5.53	1.42	0.99
	%	%	%	%
Initial Control	71.97	19.46	5.01	3.51

TABLE 8--AVERAGE COMPOSITION OF ANIMALS, FINAL

Group		Water	Protein	Fat	Ash	Total
I	%	63.64	16.36	15.21	3.70	98.91
	Gm.	38.63	9.94	9.25	2.25	
II	%	64.56	16.75	14.01	3.75	99.07
	Gm.	36.63	9.49	7.96	2.13	
III	%	63.95	16.28	15.13	3.57	98.93
	Gm.	37.80	9.60	8.95	2.11	
IV	%	67.15	18.60	9.40	3.83	98.98
	Gm.	43.28	11.75	6.11	2.49	
V	%	62.10	18.77	14.85	3.26	98.98
	Gm.	77.12	23.22	18.37	4.03	
VI	%	63.69	16.55	15.45	3.60	99.29
	Gm.	42.51	11.00	10.39	2.42	
VII	%	62.86	16.34	16.13	3.64	98.97
	Gm.	43.62	11.24	11.33	2.55	
VIII	%	63.34	17.77	14.85	3.46	99.42
	Gm.	58.60	16.24	13.86	3.23	
IX	%	64.33	18.73	12.88	3.39	99.33
	Gm.	73.42	21.23	17.74	3.88	
X	%	63.61	18.46	13.96	3.21	99.24
	Gm.	74.60	21.59	16.38	3.77	
XI	%	63.94	19.62	13.02	3.19	99.77
	Gm.	93.25	28.61	19.00	4.65	