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NUTRIENTS IN PROCESSED FOODS

proteins

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chapter 2

amino acid requirements by age and sex

by
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INTRODUCTION

The role of dietary protein is to provide the organism with enough material for the synthesis of its own body proteins plus other special nitrogenous metabolites, such as some hormones of peptide-like nature, and metabolically active amino acid derivatives. All the functions mentioned are fundamental.

Quantitatively, however, the first process (that is, the synthesis of body protein) is, by and large, the most demanding process. Ultimately, the materials provided by dietary proteins for the functions outlined are sufficient nitrogen and sulfur in a reduced metabolically utilizable form and a number of the amino acids which the enzymatic systems of the body are not capable of synthesizing, the so-called essential or indispensable amino acids.

Of the total number of amino acids which constitute body proteins in general, nine for the infant and possibly only eight for the older ages are in this category. These are histidine (infant only), isoleucine, leucine, lysine, methionine (+ cystine), phenylalanine (+ tyrosine), threonine, tryptophan, and valine. All the others are called non-essential or dispensable amino acids and can be synthesized from amino nitrogen and carbon-hydrogen-oxygen containing metabolites.

It follows, therefore, that the qualification of a protein as nutritionally adequate depends primarily on its capacity to satisfy nitrogen and essential amino acid requirements. Nitrogen and amino acid requirements become, thereby, the exclusive logical yardstick to measure protein quality; and precise knowledge about these requirements becomes basic, both in theory and in practice.

This paper will discuss the evidence that amino acid requirements vary with age in relation to total nitrogen requirements and this fact determines that the nutritional quality of a protein will differ, depending on the age of the subjects consuming it.

It has taken some time to acquire data regarding amino acid requirements, and there are still important gaps of information which have to be filled. Only when we have this information will we be able to apply a rational approach to the problem of predicting protein nutritional quality and to the even more complex problem of combating protein malnutrition.

AMINO ACIDS REQUIREMENTS AT DIFFERENT AGES

For infants, two different sources of information are available. Holt and Snyderman with their research group[1] determined the level of intake of each essential amino acid which would maintain expected normal growth and nitrogen retention in young infants. They used synthetic diets made up of a mixture of 18 amino acids in the proportion found in breast-milk and proposed a table of requirements based on the intake per kilogram per day which was adequate for all subjects.

Fomon and Filer[2] fed infants a variety of infant formulas and determined the minimum intakes of these for adequate growth in all the infants. They then calculated, from the composition of the protein in the formulas, the amount of each essential amino acid received by the infants. Since the two approaches gave data in relatively good agreement, a composite of the lowest values from the two sets of information has been proposed to represent the requirements of infants 0 to 6 months of age.

The only other children's age group for which there are some data is for preadolescent children, reported by Nakagawa, et al.[3-6] Most of the subjects were between 10 and 12 years of age. The final figures proposed by these authors were based on experimentally determined lowest intakes required to produce adequate nitrogen balance in all the subjects. They used mixtures of pure essential amino acids and glycine as a source of non-essential nitrogen.

There is reason to feel some uncertainty as to whether these figures are minimum values. The increments between intakes in the experimental design were large and therefore it cannot be assumed that the level which gave positive nitrogen balance was the lowest possible. They are, however, the only data available.

Amino acid requirements for adults are available from several sources. The studies of Rose and his group carried out with young men[7] utilized a diet of mixtures of pure essential amino acids with glycine and urea as sources of non-essential nitrogen. Their requirement figures were based on the level of intake which resulted in positive balance. The individual variability was large, and the authors selected the intake of the subject with the highest requirement.

The studies in women by several groups of investigators[8] used as criteria the attainment of nitrogen equilibrium in all subjects. This difference is obviously a more plausible explanation for the higher values for men than for women, even when expressed per kilogram of body weight, than a true sex difference.

Hegsted,[9] using the data for women available in the literature, published in 1963 the figures derived by regression analysis between intake and nitrogen balance, basing the requirements on the point at which the regression line crossed the line of nitrogen equilibrium. These figures have been most widely accepted.

The suspicion regarding these data would be that they are underestimates. One general criticism to these studies in adults is the failure to subtract skin plus miscellaneous nitrogen losses. According to estimates by FAO/WHO[10] these may amount to about 5 mg/kg/d.

On these bases, it is likely that Rose's figures are, in fact, more realistic. Rounded figures, in general slightly lower than Rose's and somewhat higher than Hegsted's, have been tabulated by FAO/WHO.[10]

The results for the three age groups discussed are summarized in Table 1. It is impossible within the scope of this paper to discuss in detail the several limitations of the data. Several groups of experts have dealt with this problem.[10,11]

More research is needed to improve or consolidate the information particularly in children. The very important group of pre-school age children has not been studied.

AMINO ACID REQUIREMENT PATTERNS AT DIFFERENT AGES

A useful corollary of the described studies is that they permit the calculation of amino acid patterns which, on theoretical grounds, should be ideal. From data on total protein (N × 6.25) requirements for age estimated as described elsewhere, and those on amino acid requirements for the same age, one can calculate the composition in essential amino acids of such "ideal" proteins for the different age groups. These, as estimated by FAO/WHO, are given in Table 2.

Despite some general agreement among the data, there are inconsistencies in the tendencies of individual amino acid requirements to vary with age. It is not clear to what extent these consistencies are due to the different methods used, or are instead true age differences. On biological bases it is difficult to accept, for instance, that the school age child would need a protein more concentrated in lysine than the infant.

One obvious fact is that the requirement of total essential nitrogen as percent of total nitrogen is much lower in the adult than in the infant. The data for 10- to 12-year-old children would suggest that the drop is slow up to at least this age, but we have to wait for more information on intermediate age groups between infancy and adulthood to draw definite conclusions.

The use of patterns specific for different age groups is a much more logical approach for judging proteins for their nutritional quality than the use of one single pattern as has previously been the practice. Single patterns proposed have been made to fit the requirements of amino acids of the pre-school child and they obviously would underestimate the quality of a protein for the adult.

When proteins are properly scored against age-specific amino acid requirement patterns, their nutritional value is age-dependent; a protein may prove very inadequate for the infant and still very adequate for the adult. On these bases, the nutritional value of a protein can be defined as the extent to which it, when ingested in sufficient quantity to satisfy the nitrogen requirement of the individual, will satisfy his requirements for each essential amino acid. This concept can be represented by the following equation:

$$\text{"Protein Quality Index"} = \frac{\text{Requirement of Protein (N} \times 6.25\text{) for age} \times 100}{\text{Amount of test protein to satisfy requirement of most limiting amino acid of subjects of the same age.}}$$

On this premise, examine cow's milk and corn protein for adults and for infants. Tables 3 to 6 give the basic calculations. All the data on amino acid composition of foods used throughout this work is from FAO.[12] To construct the column of requirements (first column of figures), the following procedure has been followed for each group:

Protein Requirement in gm/kg/d × Amino Acids in the Amino Acid Requirement Pattern in mg/gm.

The amino acid requirement patterns for infants and adults are those given in Table 2. The protein requirements are from FAO/WHO[10] as follows:

Infant 3 to 6 months	1.85 gm/kg/d
Adults (both sexes)	0.55 gm/kg/d

In Table 7 the summary of the "protein quality index" may be obtained for each protein in both age groups. It is clear that the figures obtained are age-dependent.

ESTIMATES WITH PRE-SCHOOL CHILDREN; TESTING THE FAO/WHO PROVISIONAL PATTERN FOR THIS AGE GROUP

As mentioned before, there are no experimentally determined amino acid requirement figures for the pre-school age child. FAO/WHO have proposed an amino acid pattern (mg/gm protein) which assumingly would be adequate for the preschool child. In other words, a protein with that concentration and proportions of essential amino acids would be "ideal" for this age group. Such a pattern is given in Table 8.

Using this pattern, we have estimated the "protein quality index" of cow's milk protein and of a corn-bean protein mixture containing 76 percent protein from corn and 24 percent protein from beans. The results of these theoretical estimates are presented in Tables 9 and 10.

The first two columns of numbers in each table correspond to the average amino requirements and the average + 30 percent (2 SD) for 2-year-old children.[10] The latter are supposed to cover 97.5 percent of the population. It can be seen that cow's milk protein gives a "protein quality index" of 100 percent since the amount to be ingested to cover the requirement of the most limiting amino acid (TSAA) is the same as the protein requirement.

On the other hand, the corn-bean protein mixture ("76 to 24") has a theoretical utilization value ("protein quality index") of 69 percent since 1.33 gm/kg/d are needed to satisfy the requirement of the most limiting amino acid (lysine) compared to the protein ($N \times 6.25$) requirement of only 0.90 gm/kg/d of "ideal" protein.

We have had the opportunity to test these figures experimentally in children of about this age and determine whether the theoretical predictions hold in experiment. The results are graphically represented in Figures 6 and 7.

The regression line indicates that the value of x for the value of 20.7 mg N/kg/d retention (estimated adequate for this age) is 0.906 gm/kg/d for milk protein and 1.38 gm/kg/d for corn-bean protein "76 to 24." The line for the 95 percent confidence limits crosses the 20.7 mg retention line at 1.20 gm/kg/d for milk and 1.70 gm/kg/d for corn-bean protein.

The agreement with the theoretically predicted values (0.90 and 1.20 gm for milk protein; 1.33 and 1.74 gm for corn-bean protein "76 to 24") is remarkably good. Table 11 illustrates in a different form the reasons for this agreement.

These results suggest that the "provisional pattern" is not far from correct, at least with regard to TSAA and lysine. It also illustrates the practical predictive value of the "protein quality index" approach.

TESTING THE "PROTEIN QUALITY INDEX" FOR ADULTS

On the basis of the calculations in Table 6 showing that corn-protein has a theoretical "protein quality index" of 95 percent for the adult, we planned an experiment with men to prove the hypothesis that a diet based principally on corn is adequate for the protein needs of the adults. The essential components of the diet were corn, avocado, cassava, banana, and cream, with 80 percent of the protein coming from corn.

The subjects were young (ages 18 to 22), healthy, army men living under ordinary conditions of army life. Table 12 summarizes the pertinent data from this experiment. It can be appreciated that the protein intake from vegetable sources and predominantly from corn is perfectly adequate.

Table 13, calculated retrospectively, explains the excellent results obtained with this protein. Notice that, on theoretical basis, such good behaviour could have been predicted since the diet, at the level ingested, provided an estimated 128 percent of the lysine requirement and 111 percent of the tryptophan requirement—the two most limiting amino acids. The "protein quality index" of the protein is shown in Table 14 to be over 100 percent.

The results are reassuring in that they are suggestive of the relative soundness of the amino acid requirement figures for the adult man as proposed by FAO/WHO.[10]

Table 1.
Estimated Amino Acid Requirements (mg/kg/day).*

Amino Acid	Infants	Children 10-12 Yrs.	Adults
Histidine	28	—	—
Isoleucine	70	30	10
Leucine	161	45	14
Lysine	103	60	12
TSAA	58	27	13
TAAA	125	27	14
Threonine	87	35	7
Tryptophan	17	4	3.5
Valine	93	33	10

*Source—FAO/WHO, 1972.

Table 2.
Suggested Patterns of Amino Acid Requirements (mg/gm Protein).*

Amino Acid	Infant**	School Child** (10-12 yrs.)	Adult**
Histidine	14	—	—
Isoleucine	35	37	18
Leucine	80	56	25
Lysine	52	75	22
TSAA	29	34	24
TAAA	63	34	25
Threonine	44	44	13
Tryptophan	8.5	4.6	6.5
Valine	47	41	18
Total			
+ Histidine	373	—	—
− Histidine	359	326	152

*Source—FAO/WHO, 1972.
**Calculated on the basis of the following protein requirement figures: Infant 2.0 gm/kg/day; School Child 0.8 gm/kg/day; and Adult 0.55 gm/kg/day.

Table 3.
Scoring of Cow's Milk Protein Against Amino Acid and Protein Requirements of Infants 3 to 6 Months Old.

Amino Acid	Amino Acids in 1.85 gm of "Ideal" Protein* (mg)	Amino Acid Composition of Milk Protein (mg/day)	Intake of Milk Protein to Satisfy A.A. Requirement of Infant 3-6 Months Old (gm/kg/day)
Isoleucine	65	47	1.38
Leucine	148	95	1.56
Lysine	96	78	1.23
TSAA	54	34	1.59
TAAA	116	101	1.15
Threonine	81	44	1.84
Tryptophan	15.7	14.2	1.10
Valine	87	58	1.50
Histidine	26	27	0.96

$$\text{Protein quality index} = \frac{1.85}{1.84} = 1.00\%$$

*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy the infant requirements.

Table 4.
Scoring of Corn Protein Against Amino Acid and Protein Requirements of Infants 3 to 6 Months Old.

Amino Acid	Amino Acids in 1.85 gm of "Ideal" Protein* (mg)	Amino Acid Composition of Corn Protein (mg/gm)	Intake of Corn Protein to Satisfy A.A. Requirements at 3-6 Months (gm/kg/day)
Isoleucine	65	37	1.76
Leucine	148	125	1.18
Lysine	96	27	3.55
TSAA	54	35	1.54
TAAA	116	87	1.33
Threonine	81	36	2.25
Tryptophan	15.7	6.1	2.57
Valine	87	48	1.81
Histidine	26	27	0.96

$$\text{Protein quality index} = \frac{1.85}{3.55} = 52\%$$

*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy the infant requirements.

Table 5.
Scoring Cow's Milk Protein Against Amino Acid and Protein Requirements of Adults.

Amino Acid	Amino Acids in 0.55 gm of "Ideal" Protein* (mg)	Amino Acid Composition of Milk Protein (mg/gm)	Intake of Milk Protein to Satisfy Amino Acid Requirements of Adults (gm/kg/day)
Isoleucine	9.9	47	0.21
Leucine	13.8	95	0.15
Lysine	12.1	78	0.16
TSAA	13.2	34	0.39
TAAA	13.8	101	0.14
Threonine	7.2	44	0.16
Tryptophan	3.6	14.2	0.25
Valine	9.9	58	0.17

$$\text{Protein quality index} = \frac{0.55}{0.39} = 141\%$$

*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy the adult requirement.

Table 6.
Scoring Corn Protein Against Amino Acid and Protein Requirements of Adults.

Amino Acid	Amino Acids in 0.55 gm of "Ideal" Protein* (mg)	Amino Acid Composition of Corn Protein (mg/gm)	Intake of Corn Protein to Satisfy Amino Acid Requirements of Adults (gm/kg/day)
Isoleucine	9.9	37	0.27
Leucine	13.8	125	0.11
Lysine	12.1	27	0.45
TSAA	13.2	35	0.38
TAAA	13.8	87	0.16
Threonine	7.2	36	0.20
Tryptophan	3.6	6.1	0.58
Valine	9.9	48	0.21

$$\text{Protein quality index} = \frac{0.55}{0.58} = 95\%$$

*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy the adult requirement.

Table 7.
Protein Quality Index of Cow's Milk and Corn Protein in Relation to Age.

	Cow's Milk	Corn
Infant	100	52
Adult	141	95

Table 8.
Provisional Amino Acid Scoring Pattern.*

Amino Acid	mg/gm Protein
Isoleucine	40
Leucine	70
Lysine	55
TSAA	35
TAAA	60
Threonine	40
Tryptophan	10
Valine	50
Total	360

*Source—FAO/WHO, 1972.[10]

Table 9.
Scoring Cow's Milk Protein Against Protein Requirements of Pre-School Children—2-Year-Olds—and Their Estimated Amino Acid Requirements Based on FAO/WHO 1972 Provisional Pattern.

	Amino Acids in 0.90 gm of "Ideal" Protein*	Amino Acids in 1.20 gm of Protein Pattern		Intake of Milk Protein to Satisfy:	
Amino Acid	*Average Requirement (mg)*	*Average + 30% (mg)*	Amino Acid Composition of Milk Protein (mg/gm)	*Average Requirement (gm/kg/day)*	*Average + 30% (gm/kg/day)*
Isoleucine	36	48	53	0.68	0.91
Leucine	63	84	99	0.64	0.85
Lysine	50	66	73	0.76	0.90
TSAA	32	42	35	0.90	1.20
TAAA	54	72	98	0.55	0.73
Threonine	36	48	42	0.86	1.14
Tryptophan	9	12	14.2	0.63	0.84
Valine	45	60	64	0.70	0.94

$$\text{Protein quality index} = \frac{0.90}{0.90} = 100\%$$

*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy the requirements of children 2 years of age.

Table 10.
Scoring a Corn-Bean Protein Mixture (74 to 26) Against Protein Requirements of Pre-School Children —2-Year-Olds— and Their Estimated Amino Acid Requirements Based on FAO/WHO 1972 Provisional Pattern.

Amino Acid	Amino Acids in 0.90 gm of "Ideal" Protein*	Amino Acids in 1.20 gm of Protein Pattern	Amino Acid Composition of Corn-Bean Protein Mixture (76-24) (mg/gm)	Intake of Corn-Bean Protein Mixture to Satisfy:	
	Average Requirement (mg)	*Average + 30% (mg)*		*Average Requirement (gm/kg/day)*	*Average + 30% (gm/kg/day)*
Isoleucine	36	48	38	0.95	1.26
Leucine	63	84	114	0.55	0.74
Lysine	50	66	38	1.33	1.74
TSAA	32	42	31	1.03	1.35
TAAA	54	72	85	0.64	0.85
Threonine	36	48	37	0.97	1.30
Tryptophan	9	12	7	1.28	1.71
Valine	45	60	48	0.94	1.25

$$\text{Protein quality index} = \frac{0.90}{1.33} = 69\%$$

*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy the requirements of children 2 years of age.

Table 11.
Contribution of 1.20 Grams of Cow's Milk Protein and of 1.70 Grams of Corn-Bean Protein Mixture "76 to 24" to the Theoretical Amino Acid Requirements of the 2-Year-Old Child.

Amino Acid	Requirement* (mg/day)	Amino Acids in 1.20 gm of Cow's Milk Protein (mg)	Amino Acids in 1.70 gm of Corn-Bean Protein Mixture "76-24" (mg)
Isoleucine	48	64	65
Leucine	84	119	194
Lysine	66	88	65
TSAA	42	42	53
TAAA	72	118	144
Threonine	48	50	63
Tryptophan	12	17	12
Valine	60	77	82

Based on the amounts of amino acids in 1.20 gm of a protein with the "provisional" amino acid pattern of FAO/WHO.

Table 12.
Nitrogen Balance in Adults Receiving a Diet Predominantly Based on Corn.*

Subject	Body Weight (kg)	Protein Intake (gm/kg/day) Corn	Protein Intake (gm/kg/day) Total	Nitrogen Balance** (gm nitrogen/day)
1	53.2	0.48	0.60	+0.04
2	59.1	0.43	0.54	+0.06
3	57.9	0.44	0.55	+0.60
4	55.8	0.45	0.57	+1.32
5	55.8	0.45	0.57	+1.28
6	58.5	0.44	0.55	+0.24
7	59.5	0.43	0.54	+0.68
8	60.0	0.42	0.53	+0.42
9	57.8	0.46	0.56	−0.08
10	57.9	0.44	0.55	+0.74
Average	57.6	0.44	0.56	+0.53

*Source—FAO/WHO, 1972.
**Corrected for skin plus miscellaneous losses estimated at 5 mg N/kg/day.

Table 13.
Contribution of Corn and Total Dietary Protein to Meeting Amino Acid Requirements of Adult Subjects.

Amino Acid	Requirement* (mg/kg/day)	Amino Acids** Ingested from Corn Protein (mg/kg/day)	Amino Acids*** Ingested from Total Protein (mg/kg/day)	Percent of Requirements Satisfied by: Corn	Percent of Requirements Satisfied by: Total Diet
Isoleucine	10.3	16	18	153	173
Leucine	14.3	56	61	386	421
Lysine	12.5	12	16	96	128
TSAA	13.7	16	18	116	130
TAAA	14 3	39	45	273	315
Threonine	7.4	16	19	213	253
Tryptophan	3.7	3.2	4.1	86	111
Valine	10.3	22	26	212	250

*Source—FAO/WHO, 1972.
**Average corn protein intake: 0.44 gm/kg/day.
***Average protein intake from corn plus banana plus cassava plus avocado plus cream = 0.56 gm/kg/day.

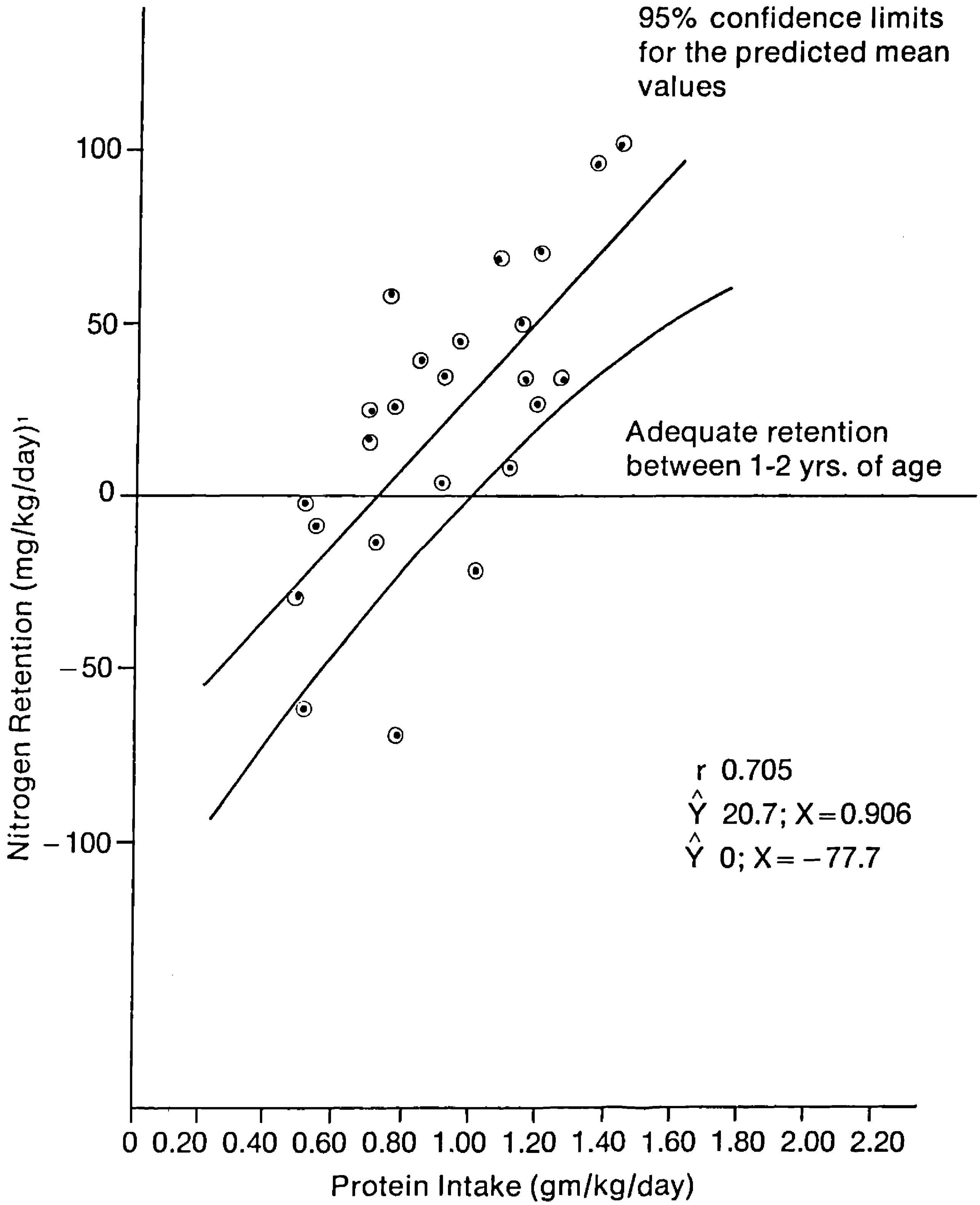
Table 14.
Theoretical Intake of "Corn-Diet" Protein to Satisfy the Amino Acid Requirements of Adult Men Subjects.

Amino Acid	Amino Acids in 0.57 gm of "Ideal" Protein* (mg)	Amino Acid Content of "Corn-Diet" Protein (mg/gm)	Intake of "Corn-Diet" Protein to Meet Amino Acid Requirements (gm/kg/day)
Isoleucine	10.3	34	0.30
Leucine	14.3	116	0.12
Lysine	12.5	31	0.41
TSAA	13.7	33	0.42
TAAA	14.3	84	0.17
Threonine	7.4	36	0.21
Tryptophan	3.7	7.8	0.48
Valine	10.3	48	0.22

$$\text{Theoretical quality index} = \frac{0.57}{0.48} \times 100 = 119\%$$

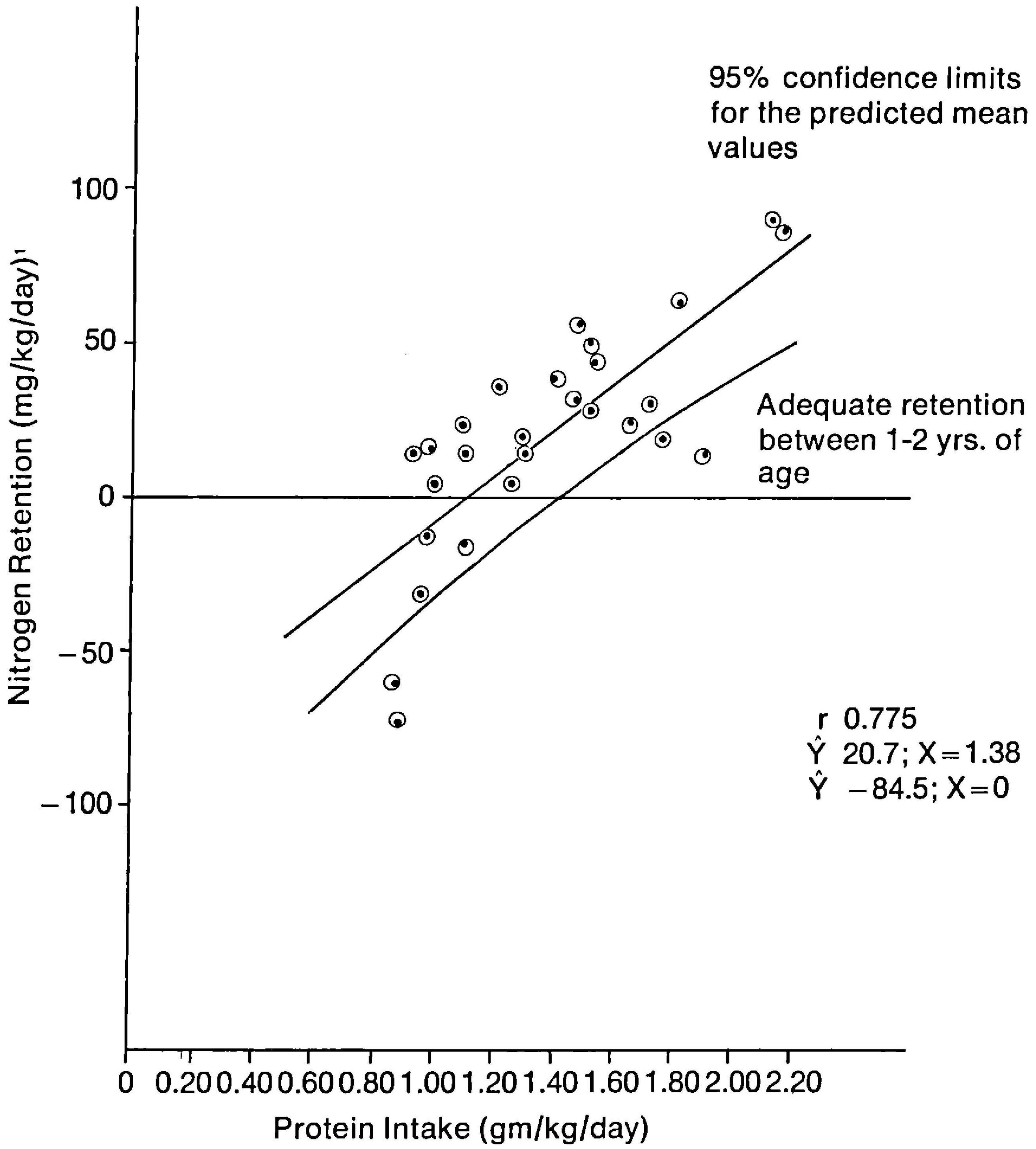
*Theoretical protein containing essential amino acids in adequate proportion and concentration to satisfy adult requirement; 0.57 gm/kg/day is the safe level of intake of FAO/WHO, 1972.

Figure 6.
Protein Quality Index—Age Group 1 to 2—of Cow's Milk.*



*Source—*INCAP.*, 72: 1335.

Figure 7.
Protein Quality Index—Age Group 1 to 2—of Corn-Bean Mixture.*



*Source—*INCAP.*, 72: 1336.

summary

1. The qualification of a protein as nutritionally adequate depends primarily on its capacity to satisfy nitrogen and essential amino acid requirements.

2. Nitrogen and amino acid requirements are, therefore, the logical yardstick to measure protein quality, and the need for precise knowledge about them is basic.

3. Nitrogen and amino acid requirements vary with age, but not at the same rate; consequently, the nutritional quality of a protein will vary depending on the age of the individual consuming it.

4. There is an urgent need for more research on amino acid requirements at different ages, especially between infancy and adulthood. From the data resulting from that research, it would be possible to derive age-specific "protein patterns" to assess protein and amino acid nutrition at different ages more exactly. This is of theoretical and practical importance.

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