ADVANCES IN EXPERIMENTAL MEDICINE AND BIOLOGY
Volume 105

# NUTRITIONAL IMPROVEMENT OF FOOD AND FEED PROTEINS

Edited by Mendel Friedman

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PLENUM PRESS • NEW YORK AND LONDON

Library of Congress Cataloging in Publication Data

Symposium on Improvement of Protein Nutritive Quality of Foods and Feeds, Chicago, 1977.
Nutritional improvement of food and feed proteins.

(Advances in experimental medicine and biology; 105)
Sponsored by the Protein Subdivision of the Division of Agricultural and Foods Chemistry of the American Chemical Society.
Includes index.
1. Proteins in human nutrition—Congresses. 2. Proteins in animal nutrition—Congresses. 3. Amino acids in human nutrition—Congresses. 4. Amino acids in animal nutrition—Congresses. I. Friedman, Mendel. II. American Chemical Society. Division of Agricultural and Foods Chemistry. Protein Subdivision. III. Title. IV. Series. [DNLM: 1. Dietary proteins. 2. Plant proteins. 3. Amino acids. 4. Food, Fortified. 5. Nutrition. W1 AD559 v. 105/QU55.3 N976]
TX553.P7S8 1977 641.1'2 78-17278
ISBN 0-306-40026-X

Proceedings of the Symposium on Improvement of Protein Nutritive Quality of Foods and Feeds, sponsored by the Protein Subdivision of the Division of Agricultural and Food Chemistry of the American Chemical Society, Chicago, Illinois, August 29–September 2, 1977, with additional invited contributions.


A Division of Plenum Publishing Corporation
227 West 17th Street, New York, N.Y. 10011



Printed in the United States of America

# Preface

The nutritional quality of a protein depends on the proportion of its amino acids-especially the essential amino acids-their physiological availability, and the specific requirements of the consumer. Availability varies and depends on protein source, interaction with other dietary components, and the consumer's age and physiological state.

In many foods, especially those from plants, low levels of various essential amino acids limits their nutritive value. This is particularly important for cereals (which may be inadequate in the essential amino acids isoleucine, lysine, threonine, and trytophan) and legumes (which are often poor sources of methionine). Moreover, these commodities are principle sources of protein for much of the earth's rapidly growing population.

At the current annual growth rate of about 2 percent, the world population of about 4 billion will increase to 6.5 billion by the year 2000 and to 17 billion by the year 2050. Five hundred million people are presently estimated to suffer protein malnutrition, with about fifteen thousand daily deaths. The ratio of malnourished to adequately nourished will almost surely increase. For these reasons, and especially in view of the limited availability of high quality (largely animal) protein to feed present and future populations, improvement of food and feed quality is especially important.

The key questions in my mind are "What may or will happen if we do not develop new and improved food and feed sources? What are the consequences of population pressures for our future well-being?" In his analysis of the subject, Robert R. Heilbronner (*An Inquiry into the Human Prospect*, W. W. Norton, 1975) foresees dire prospects which include: (a) rule of the world by military-socialist dictatorships; (b) seizures of weak nations by strong ones; (c) use of nuclear blackmail by underdeveloped countries to transfer wealth; and (d) deterioration of the environment, whereby exponentially growing emission of man-made heat will cause drastic climactic changes and major decreases in industrial and agricultural production. In a related analysis (*Engineering Science*, pp. 22-36, 1956), Sir

Charles Darwin also suggests that man will come to a 'semi-bestial' existence (his grandfather did not have this type of 'evolution' in mind when he wrote *Origin of Species* and *The Descent of Man*). Although Fred Hoyle (*ibid.*, pp. 8-10) and Robert Heilbronner suggest that human negative feed-back processes will exercise a dampening effect on the impending crisis, such feed-backs may not suffice to prevent it. (A result of important feed-back processes is the differential growth rate of the world's population. Western Europe, the United States, and apparently also the Peoples Republic of China, seem to be approaching true zero growth, in contrast to Latin America, Africa, and most other parts of Asia, which are growing by 2 to 3 percent annually).

We are, therefore, challenged to respond to humanity's common danger. I feel that as scientists interested in proteins in all aspects, we are indeed responding to this challenge. Aside from limiting population growth, which is a sociological and political problem, our work as agronomists, plant breeders, animal scientists, food chemists, food technologists, nutritionists, dieticians, physicians, toxicologists, agricultural economists, and industrialists can help avoid and alleviate shortages of high quality foods and feeds and thus counter and mitigate some of the more serious threats to the quality of life for ourselves and our descendants. Our objective should be to improve the quality and quantity of available food and feed sources by all feasible methods. Much new chemistry and engineering is needed to support genetics and agronomy. Food fortification and supplementation need better guidance based on research. Deleterious side reactions in food storage and processing need to be eliminated or minimized. Ways to measure protein nutritional quality based on information from chemical, biochemical, microbiological, animal, and human studies need to be correlated and optimized. New protein food sources need to be developed; related toxicological and nutritional problems need solutions.

Because I feel that the most important function of a symposium is dissemination of insights and catalysis of progress by bringing together ideas and experiences needed for synergistic interaction among different, yet related disciplines, in organizing the Symposium on "Improvement of Protein Nutritive Quality of Foods and Feeds" (sponsored by the Protein Subdivision of the Division of Agricultural and Food Chemistry of the American Chemical Society, Chicago, Illinois, August 29-September 2, 1977), I invited papers discussing one or more of the following topics: (1) Improvement of protein quality by genetic methods; (2) Fortification of foods and feeds with essential amino acids, amino acid analogs, or derivatives; (3) Enrichment of foods and feeds with protein supplements; (4) Use of special processes such as the plastein reaction to maximize protein quality and utilization; (5) Use of protected amino acids and proteins in ruminant feeds to increase meat, milk, and wool production; (6) Chemical and microbiological syntheses of essential amino acids; (7) Interactions of supplemental amino acids or proteins with other food ingredients during storage and processing and ways to minimize such undesirable interactions; (8) Economic aspects, including calculation of least cost-optimum quality supplemented foods and feeds; (9) Animal and human feeding tests of nutritional availability of amino acids or proteins in supplements; and (10) Safety of supplemented or specially processed foods and feeds, including amino acid antagonisms *in vivo*.

In addition, many scientists accepted invitations to contribute papers to this volume. Indeed more than half the papers are specially written, invited contributions. This book is, therefore, a hybrid between a symposium proceedings and a collection of invited contributions.

This volume brings together outstanding international authors from ten countries, who, in forty papers, thoroughly discuss various ways to improve foods and feeds. Though an adequate summary is not possible in a preface, I wish to call special attention to several manuscripts. First, F. Monckeberg and C. O. Chichester describe in a particularly enlightening way the interdependent efforts among several scientific disciplines, government agencies, and industry to successfully develop a fortified food formula for children in Chile. Related discussions of nutrition intervention programs in Guatemala are ably presented by R. Bressani, L. G. Elias, and J. E. Braham, and in India, by R. P. Devadas. These papers and related ones by A. A. Betschart on bread fortification and by V. H. Holsinger on beverage fortification will serve well those planning to commercialize fortified, supplemented, or complemented solid and liquid foods for human consumption. A note of caution is, however, needed. As H. N. Munro points out, excessive intake of certain free amino acids in (fortified) foods can have undesirable physiological consequences. The methods for predicting protein quality described in three papers by J. M. McLaughlan, A. A. Woodham, and N. J. Benevenga and D. G. Cieslak are also noteworthy because the ideal method for protein quality evaluation has been so elusive. Another immediate concern is the current widespread interest among nutritionists and consumers about the role of plant fiber in human nutrition. I am therefore pleased that G. A. Spiller has contributed a critical overview of this subject, co-authored by Joan Gates. This attempt to define the problem precisely will undoubtedly stimulate further nutritional and medical progress. Finally, the comprehensive paper by S. G. Platt and J. A. Bassham on the potential for controlling photosynthesis to increase protein production offers great promise for more efficient photosynthesis, the ultimate source of our indispensable food and feed protein.

The papers are being published by Plenum under the title NUTRITIONAL IMPROVEMENT OF FOOD AND FEED PROTEINS as a volume in the series Advances in Experimental Medicine and Biology. This book is intended to complement the previously published *Chemistry and Biochemistry of the Sulfhydryl Group in Amino Acids, Peptide, and Proteins* (Pergamon, 1973); *Protein-Metal Interactions* (Plenum, 1974); *Protein Nutritional Quality of Foods and Feeds. Part 1: Assay Methods--Biological, Biochemical, and Chemical* (Dekker, 1975); *Protein Nutritional Quality of Foods and Feeds. Part 2: Quality Factors--Plant Breeding, Composition, Processing, and Antinutrients* (Dekker, 1975); *Protein Crosslinking: Biochemical and Molecular Aspects* (Plenum, 1977); *Protein Crosslinking: Nutritional and Medical Consequences* (Plenum, 1977). (I wrote the sulfhydryl book and edited the others). I hope that these books will be a valuable resource for further progress in protein chemistry, agriculture, food science, animal and human nutrition, biochemistry, and medicine; areas of world-wide urgency.

I am particularly grateful to all contributors for excellent cooperation, to Wilfred H. Ward for constructive contributions to several manuscripts, to my son, Kenneth A. Friedman, for his help in preparing the index, and to Miles Laboratories and Gerber Baby Products for financial assistance.

I dedicate this book to my parents, Rachel and Efroim Frydman, who nurtured their children with love under extraordinary circumstances.

Mendel Friedman
Moraga, California
July 1978

*The earth is full of the fruit of Thy works.*
*Thou causest grass to spring up for cattle,*
*And herbs for the service of man.*
*Thou bringest forth bread out of the earth*
*To sustain man's life,*
*And wine to gladden his heart.*

*Psalm 104: 28-33*

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# POSITION PAPER ON RDA FOR PROTEIN FOR CHILDREN

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## ABSTRACT

The Recommended Dietary Allowances (RDA) by the National Academy of Sciences are revised approximately every five years. The RDA are compromise opinions of highly qualified nutritional scientists based on interpretations of available data. As with any interpretations and opinions not founded on definitive information, they are subject to challenges. The RDA for protein for 7- to 9-year-old children have been adjusted downward from 60 g in 1958 to 36 g in 1974, a 40% reduction. Data from our laboratories have shown positive apparent nitrogen balances on intakes as low as 18 g daily when no allowances were made for integumental and other nitrogen losses, however, based on accumulative data over several years we calculate the protein requirement to be 45 g daily from a typical American diet. If a safety factor of 30% is added the allowance would become 58.5 g. Currently the RDA for protein for the 7- to 10-year-old child supplies 6% of the RDA for Calories which contrasts to 8.30 and 9.20% for adult males and females, respectively. For comparison, energy from protein as a percentage of total energy for some common foods are: white bread, 12%; corn meal 10%; white rice 7%; and wheat flour 13%.

## INTRODUCTION

Approximately every five years the Food and Nutrition Board of the National Academy of Sciences revises the Recommended Dietary Allowances. The Board, composed of active nutritional scientists, utilizes existing literature concerned with nutritional needs of various age groups. The RDA reflect the best estimates of nutrient intakes which will meet the needs of practically all healthy persons.

That these best estimates are often crude and perhaps influenced by personal bias of the current Board members is attested to by the fact that the RDA may change very dramatically in only a few years even in the absence of any significant new data on actual requirements for a given nutrient. For example, the RDA for vitamin E for the adult was decreased from 30 IU in 1968 to 15 IU per day in 1974 with very little new data on actual requirements.

The RDA for protein for 7- to 10-year-old children (Table 1) decreased from 60 g per day in 1958 to 36 g in 1974, a 40% drop (NRC, 1958 and NRC, 1974). This decrease in the RDA is the subject of this paper. We are suggesting that the 1974 RDA for protein for 7- to 10-year-old children is too low.

Obviously, the Food and Nutrition Boards for the last two revisions believed that the previous RDA for young school age children were too high. Current protein allowances, except for infants, are based on theoretical calculations assuming an average requirement for maintenance of 0.47 g of protein per kilogram of body weight per day as estimated by nitrogen balance technique. This value is increased by 30% to cover individual variation and by another 33% to correct for an average of 75% efficiency of utilization making the recommended allowance for maintenance 0.8 g of protein per kilogram of body weight per day. An allowance for growth, also corrected for inefficient utilization, is added. In the case of the 7- to 10-year-old child, the value, as corrected, is 0.4 g per kilogram per day; thus, the recommended allowance is 1.2 g of protein per kilogram of body weight or 36 g of protein daily for a 30 kilogram child. This value is in line with the FAO/WHO recommended intake of 25 g of protein per day as egg or milk protein for 7- to 9-year-old children (FAO/WHO, 1973). Twenty-five grams when corrected for 75% efficiency of utilization would become 34 g per day for the 28.1 kg child used as a reference by the FAO/WHO group.

Though the RDA and FAO/WHO values agree closely, there are important questions about the recommended allowances. First, these recommended allowances are not based on research data with children, but are extrapolations from data obtained with adults. The Food and Nutrition Board, as well as the FAO/WHO Expert Panel, considered existing data available for children but were faced with widely varying estimates of requirements ranging from 0.7 to 3.5 g of protein per kilogram of body weight (Irwin and Hegsted, 1971). Secondly, a diet recommended for the growing child should be adequate in protein concentration for non-growing adult men and women. Thirdly, our research data, as we interpret them, are not

TABLE 1

Changes in the RDA for Protein for School Age Children Since 1958

| Date | Ages Years | Protein g/day |
|---|---|---|
| 1958 | 7-9 | 60 |
| 1964 | 6-9 | 52 |
| 1968 | 6-8 | 35 |
| | 8-10 | 40 |
| 1974 | 7-10 | 36 |

supportive of the current RDA (Abernathy et al., 1966, Abernathy and Ritchey, 1972, Korslund et al., 1976), and fourthly, other qualified researchers also have proposed that the recommended allowances for adults and children be adjusted (Swaminathan et al., 1970, 1971, Swaminathan and Parpia, 1971).

Table 2 shows the 1974 Recommended Dietary Allowances for protein expressed as grams of protein per 100 kcal and energy from protein expressed as a percentage of total calories. The recommended protein concentration decreases from infancy reaching lowest level of 6% of calories at 7 to 10 years of age, then increases again reaching the highest level in the age group, 51 and above. Even though the allowances were set only after extensive debate, it almost looks as if they were proposed by meat loving adults who believe children should be allowed to come to the table only after their elders have consumed their meals. The percentages of energy from protein in cereal grains, potatoes and green leafy vegetables are higher than the level recommended for children. For comparison to the level recommended for 7- to 10-year-old children of 6%, the percentages of energy of protein from some common, non-protein-rich foods are: sweet corn, 14.6; corn flour, 8.5; corn grits, 8.3; boiled potato, 11.0; French fried potatoes, 6.3; sweet potatoes and yams, 6.0 to 8.3; white bread, 12.9; whole wheat bread, 17.3; rye, 14.5; polished rice, 7.3; green leafy vegetables 20-50; and ice cream with 10% fat, 9.3.

## NITROGEN BALANCES

We have conducted a large number of nitrogen balance studies with healthy 7- to 9-year-old children with protein intakes from commonly consumed foods ranging from 18 to 88 grams per day

TABLE 2

1974 RDA for Protein

| Age years | Energy kcal | Protein g | g Protein/ 100 kcal | % of energy from protein |
|---|---|---|---|---|
| 1-3 | 1300 | 23 | 1.77 | 7.07 |
| 4-6 | 1800 | 30 | 1.67 | 6.67 |
| 7-10 | 2400 | 36 | 1.50 | 6.00 |
| Males | | | | |
| 11-14 | 2800 | 44 | 1.57 | 6.28 |
| 15-22 | 3000 | 54 | 1.80 | 7.20 |
| 23-50 | 2700 | 56 | 2.07 | 8.30 |
| 51+ | 2400 | 56 | 2.33 | 9.33 |
| Females | | | | |
| 11-14 | 2400 | 44 | 1.83 | 7.33 |
| 15-18 | 2100 | 48 | 2.29 | 9.14 |
| 19-22 | 2100 | 46 | 2.19 | 8.76 |
| 23-50 | 2000 | 46 | 2.30 | 9.20 |
| 51+ | 1800 | 46 | 2.56 | 10.22 |

(Abernathy et al., 1966, 1970, 1972, Spence et al., 1972, Howat et al., 1975, Meiners et al., 1977). These studies varied in length from 18 to 64 days. The subjects were all judged to be healthy and free from intestinal parasites, except for pin worms which were observed and treated in a few girls. The diets were ordinary foods which supplied 1800 to 2400 kcal daily depending on the size of subjects. Any subject losing weight or in negative nitrogen balance was given additional energy in increments of 200 kcal per day and/or increments or protein if necessary. The food was provided in three meals and two snacks daily.

A summarization of nitrogen balance data from several of these studies is presented in Table 3. The percentage of total protein from animal sources ranged from 0 to 75%. The essential amino acid levels were in the range of that seen in common foods patterns of school children in the United States with lysine, sulfur containing amino acids or tryptophan being the most limiting (Abernathy et al., 1966). Except for low levels of riboflavin and

TABLE 3

Observed and Predicted Nitrogen Retention at Several Levels of Nitrogen Intake

(mg./kg. body weight/day)

| Animal Protein (% of total) | Mean Nitrogen Intake X | Mean Nitrogen Absorbed (apparent) | Mean Nitrogen Retention Observed Y | Predicted $Y^1$ |
|---|---|---|---|---|
| 74 | 432 | 401 (392-414)[2] | 35 (27-44)[2] | 50 |
| 72 | 430 | 400 (391-414) | 48 (37-55) | 50 |
| 70 | 356 | 323 (245-416) | 52 (38-76) | 47 |
| 60 | 319 | 284 (276-299) | 50 (44-53) | 45 |
| 75 | 300 | 268 (254-278) | 43 (34-59) | 44 |
| 67 | 217 | 188 (166-211) | 37 (20-55) | 35 |
| 72 | 204 | 185 (179-192) | 29 (19-37) | 33 |
| 0 | 225 | 177 (168-188) | 26 (15-34) | 36 |
| 0 | 218 | 168 (137-199) | 30 (13-42) | 35 |
| 45 | 128 | 103 (88-122) | 25 (13-43) | 20 |
| 0 | 135 | 99 (86-106) | 18 (8-26) | 21 |
| 0[3] | 128 | 89 (83-96) | 7 (4-11) | 20 |
| 30 | 104 | 78 (64-91) | 16 (11-25) | 15 |

1 - $Y = -9.10 + 0.267X - 0.0003038X^2$ prediction equation
2 - range
3 - Diet low in riboflavin and niacin

niacin in one study, the other nutrients were provided at levels approximately the RDA.

There was a highly significant linear relationship between nitrogen intake and apparent nitrogen retention, however, the best fit of the data was a slightly currilinear regression, ($Y = -9.10 + 0.276 X 0.0003038X^2$), where Y is apparent nitrogen retention and X is nitrogen intake, both in milligrams per kilograms of body weight. About 64% of the variation in retension data was accounted for by this regression.