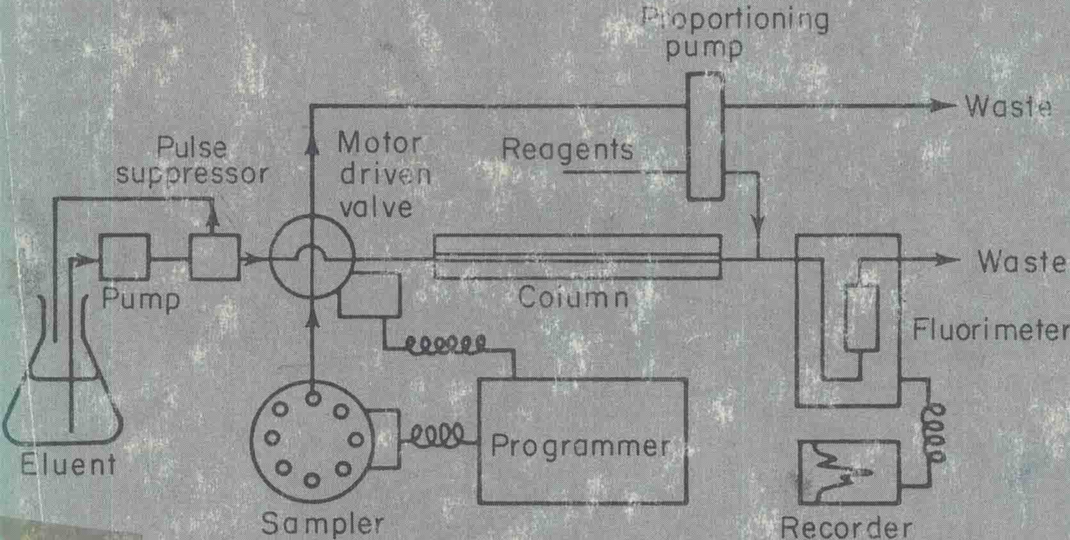
Food Science and Technology: A Series of Monographs

THE ANALYSIS OF NUTRIENTS IN FOOD



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The Analysis of Nutrients in Foods

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Preface

Having been hunter, fisher and farmer, living off a restricted area of surrounding countryside for thousands of years, man has over the past one hundred years quite suddenly been exposed to the industrial revolution and a population explosion, which have produced dramatic changes in both where and how he lives.

For example, the shift in population from rural to urban life in industrialised countries has been such that it is no longer possible to satisfy all the demands of society without recourse to the extensive use of modern agricultural practice and food technology. Without this it would not be possible to provide fresh or processed foods of good quality on a large enough scale, to preserve foods against deterioration, to prepare foods for the convenience of the consumer and, most important in the context of this book, to provide a general diet of satisfactory nutritive value.

Most of us tend to take for granted the wide variety and volume of food available to us today. We should recognise, however, that advances in agriculture and food technology with its techniques of processing, storage and distribution, have been as important to us in maintaining our nutritional standards during a period of rapid changes in society, as advances in sanitation, medical practice and pharmacology have been in eradicating disease.

Whilst recognising that continuing changes in agricultural practice and food technology will occur to improve the supply of raw materials, increase the variety of products and facilitate storage and domestic use of foods, we should not become complacent about the effects that they and our eating habits may be having on our nutritional wellbeing.

One of the key elements in monitoring our general nutritional status is reliable information on the nutrient composition of foods and it is in this area in particular that the food analyst has a major contribution to make to the advancement of nutritional research. The primary purpose of this book is therefore to provide the analyst with a reliable and generally applicable set of analytical procedures for the determination of those nutrients for which the significance in the human diet is known.

These methods are set out in standard form in Part II of this book. Because the range of food products now available is enormous and the resources of the analyst often limited, attention has been given to replacing or providing alternatives to some of the more tedious of the classical biological and chemical procedures. For example, new high performance chromatographic methods are included for certain vitamins and atomic absorption methods replace the classical chemical procedures for metals. These techniques will allow the analyst who has access to modern instrumentation to deal with large numbers of samples in a limited time. Thus the book is intended to reflect modern developments, but at the same time it recognises the widely differing operational conditions of individual analysts and hence the continuing need for and value of less sophisticated but well tested methods of analysis.

Reliable and efficient analytical procedures are not enough, however, if the analyst is to provide an effective service and contribute fully to nutrition research and development. He must, wherever possible, increase his general understanding of nutrition so that he can appreciate the objectives of any nutritional work before doing his analyses, as it is only with such information that he will be able to judge which are the most important analyses to do, put problems into their correct perspective, apply the appropriate tests and attempt to interpret data intelligently. Failure to do this will invariably result in a waste of valuable technical resources and poorly defined answers to the problem at hand.

For example, a working knowledge of data tables on the levels of nutrients in foods and average food consumption, coupled with information on the stability of various nutrients under conditions normal in agricultural practice, food processing, storage and household cooking, should form an essential part of the background against which the analyst can judge how important it is to carry out certain analyses.

Take, for example, vitamin C in milk and potatoes. Data tables for raw and processed milk will show that there is often considerable destruction of vitamin C during processing, but they show also that the total amount of the vitamin initially present in raw milk is small and that milk is, therefore, under normal patterns of food consumption, unlikely to be regarded as a significant dietary source of vitamin C. Therefore, processing losses of vitamin C from milk are nutritionally less important and may not require frequent monitoring. By contrast, potatoes supply one third to one half of the average vitamin C intake of Europeans in winter. Losses of vitamin C through processing potatoes could therefore be serious and more frequent monitoring may be justified.

In order to help the analyst to make a full and effective contribution to nutrition research and development, Part I of the book contains, in addition to further analytical background, some elementary information on the chemistry, biochemistry and biological role of the main macro- and micronutrients and introductory material on food composition, intake of nutrients and the interpretation of nutritional data. This material is in no way comprehensive but tries to illustrate the need for and value of the analyst becoming more familiar with the general background to nutritional issues before undertaking the practical work involved. This process can begin easily with this book but the reader is also strongly advised to read further into the subject via appropriate books and other literature, such as those provided in the classified bibliography at the end of Part I.

In summary, the book should be looked upon as serving two functions, the primary one being to provide the analyst with the tools of his trade in the form of a comprehensive set of relevant methods and a secondary but no less important one of introducing the analyst to the broader aspects of nutrition in a way that will help and encourage him to become an active and effective partner rather than servant of nutritional research and development.

Finally, the authors would like to acknowledge gratefully the efforts and co-operation of their many co-workers at the Unilever Research Laboratories at Colworth and Duiven, without which this book could not have been produced.

D.R.O.

April, 1978 P.V.

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PART I

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The Chemistry, Biological Role, and Analysis of Nutrients in Food

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CHAPTER 1

Chemistry and Biological Role of Macronutrients

1.1 Proteins

Proteins are polymers of which the basic units are amino or imino acids. In a protein molecule hundreds, sometimes thousands, of amino or imino acids are joined together by a characteristic linkage, the peptide bond. The basic protein structure is represented in Fig. 1 in which R can vary depending on the amino acid units from which the chain is formed, and the sequence of amino acid groups is developed in a specific way for a given protein.

In addition to the specific sequence of primary linkages which forms the backbone of protein molecules, other secondary physical or chemical linkages are present; for example, the linking of two or more chains and conformational factors make possible a multiplicity of structural differences between proteins. Thus the physical, chemical, and nutritional properties of different proteins vary with their quantitative amino acid composition, the sequence and cross-linking of the amino acid units in the protein molecule, and conformational arrangement.

Proteins in the human diet come from both animal and vegetable sources, the most important being meat, fish, milk, eggs, cereals, legumes, seeds, and

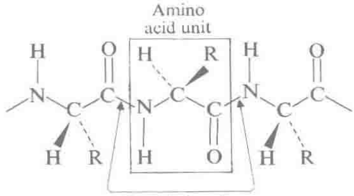

FIG. 1. The basic structure of proteins.

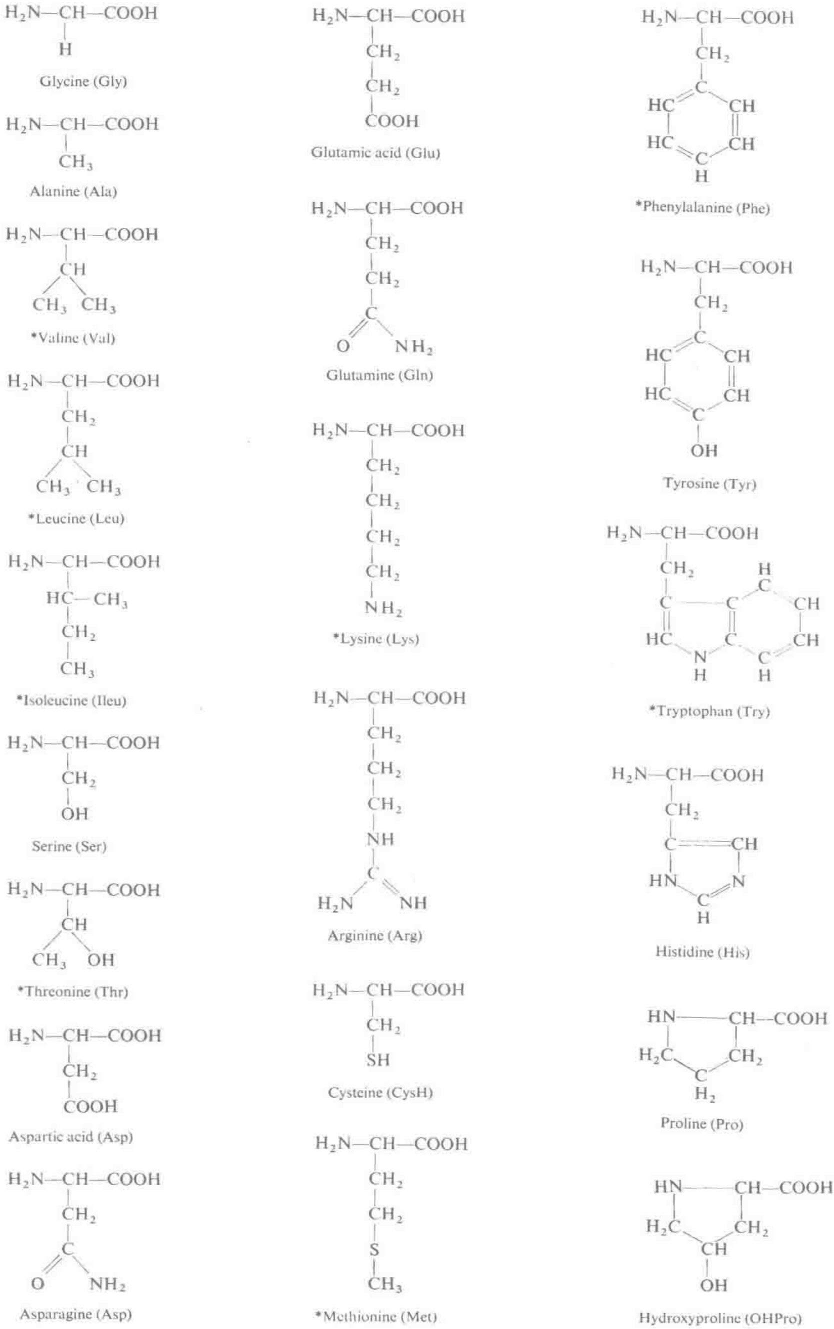

FIG. 2. Structures of amino acids and imino acids; the names of the 'essential' amino acids are marked with an asterisk(*).

nuts. When these are eaten, the proteins are digested by hydrolytic enzymes of the gastrointestinal tract and are absorbed into the bloodstream as amino acids. These amino acids are used in the synthesis of new proteins needed for growth, maintenance, and repair of body cells. Some of the amino acids required can be made in the body as the need arises but others can be obtained only from food. These latter are called essential amino acids. However, the non-essential amino acids are not necessarily less important biologically.

Twenty amino acids commonly occur in food, and eight of these are essential. These are shown diagrammatically in Fig. 2. With two exceptions these substances have a primary amino function ($-NH_2$) and a carboxyl function (–COOH) joined to the same carbon atom; hence they are termed α-amino acids. The two exceptions, proline and hydroxyproline, are α-imino acids (see Fig. 3). Egg and human milk proteins provide all the essential amino acids for normal growth and healthy life processes, provided that they are taken in adequate amounts. On the scale of nutritive value, they are at the top.

These proteins contain the amino-acids in the correct proportion for the body's need. If such a protein is fed under experimental conditions to growing animals, virtually 100% of the protein absorbed is used for protein synthesis, and none is diverted to energy production; hence the protein is said to have a Biological Value (BV) of 100. No other protein is quite as good. Cow's milk, fish, and meat come next, followed by the plant proteins, i.e. wheat, rice, beans, and nuts. For example, cow's milk protein is short of methionine and cystine and has a BV of 75; wheat protein is deficient in lysine and has a BV of only 50. In the latter case lysine is termed the 'limiting amino acid'.

Human diets do not of course consist of individual proteins, but are made up of mixtures of very many proteins. This mixing has important implications for us, since it will often happen that the mixing of different proteins of lower BV will produce a mixture with a higher BV than we might expect from the average of the separate BV's. If this occurs the proteins are said to complement one another nutritionally. The principle of complementation is best illustrated diagrammatically (Fig. 4). A practical example is bread having a BV of 50 and cheese having a BV of 75, yet a mixture of $3\frac{1}{2}$ parts bread to 1 part of cheese has a BV of 75. The reason is that the shortage of lysine in bread is made up by the surplus of lysine in cheese.

The diagram (Fig. 4) will also help to explain why complementation does not occur if both proteins in a mixture are deficient in the same amino-acid.

(a) (b)

FIG. 3. General formulae of (a) α-amino acids and (b) α-imino acids.

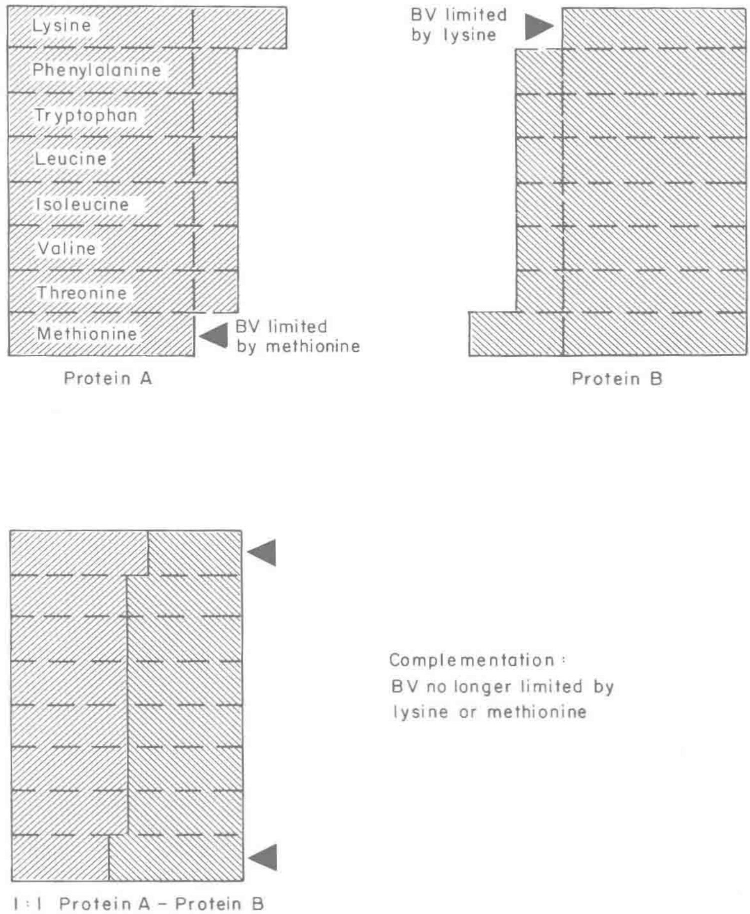

FIG. 4. Principle of complementation of proteins.

Thus a mixture of maize (BV 36) and bread (BV 50), both limited by lysine, has a BV of 43, the average of the individual values. Also, complementation between proteins does not occur if the proteins are eaten at different times. To ensure complementation, the two proteins must be eaten at the same time at the same meal, because the body has little capacity to store unused amino acids but uses them as sources of energy.

We have so far defined protein quality in terms of Biological Value, but readers will almost certainly encounter other indices of protein quality. Biological Value is defined strictly as 'the percentage of absorbed nitrogen