PROTEIN BEARING CROPS

M. Hajós-Novák
Department of Genetics and Plant Breeding, Faculty of Agricultural and Environmental Sciences, Szent István University, Gödöllő, Hungary

Keywords: crude protein, storage proteins, globulins, prolamis, glutelins, cereal proteins, vegetable proteins, essential amino acids, biological value

Contents

Summary

All the nutrients essential to man, except vitamin B_{12} and vitamin D, can be obtained from plant foods. At present only about 150 species are actively cultivated, directly for human food or as feed for animals and, of these, 30 produce 95% of human calories and proteins. Approximately, half of our food derives from rice, maize, wheat, and potato. Furthermore legumes, oat, barley and forages are very important protein sources both for humans and animals. Protein is accumulated in leaves, stems, and seeds. Seed proteins are called storage proteins. They can be classified into three main types; globulins, prolamins, and glutelins.

The cereals, the legumes, the non-seed crops other than grass, and the potato are the principal source of protein and calories. Their crude protein content is very variable. The cereals usually do not contain more than 15% of protein in their seeds. Legumes and oilseeds contain rarely less than 20% and often more. Climate, soil fertility, amount and timing of nitrogen fertilization, as well as variety, influence the protein content. Generally higher protein is accompanied by reduced grain yield.

The biological value of protein is determined by its essential amino acid content. Breeding for an improved balance of essential amino acids is even more difficult than breeding for protein content. Raising the level of lysine, threonine methionine, and/or tryptophan would enhance the nutritive value of cereals or legumes. But the potential

for such increases is limited by the fact that there is only minimal variability for amino acid composition among species, genotypes, or environments. High-lysine varieties have been produced in corn and barley. But it has been associated with reduced yields and kernel weight, greater susceptibility to ear rots and insects and abnormal starch development. As protein content increases, there has been a tendency for the lysine content in the protein to decrease. Probably, environment has no effect on essential amino acid content.

1. Protein bearing plants and the world's food supply

The world's food supply, grossly inadequate in many countries today, will need to be increased greatly in the years ahead if the basic nutritional requirements of an explosive world population are to be satisfied. Otherwise, the nutritional gap between the developed and underdeveloped countries will continue to widen.

According to Hurrell (2001) ”All the nutrients essential to man, except vitaminB_{12} and vitamin D, can be obtained from plant foods. They contain the carbohydrates, protein and fat necessary for energy production. They contain the amino acids and fats necessary to make body structures such as muscles and cell membranes, or to make the enzymes, hormones or prostaglandins that help control the main body reactions”.

There are about 350 000 plant species in the world, of which about 80,000 are edible for humans. However, at present only about 150 species are actively cultivated, directly for human food or as feed for animals and, of these, 30 produce 95% of human calories and proteins.

Field crops provide the principal source of the world's food supply. About half of our food derives from only four plant species—rice (*Oryza sativa*), maize (*Zea mays), wheat (Trticum* spp.), and potato (*Solanum tuberosum*). According to the IMPACT model, that simulates future global food demand and supply, to fulfill demands a compound annual rate of increase in maize, rice and wheat yields of 1.1% is required to 2020.

1.1 Proteins and nucleic acids

Proteins are complex organic compounds of high molecular weight. They contain carbon, hydrogen and oxygen, but in addition they all contain nitrogen and generally sulfur. Some proteins also contain the elements phosphorus, iron and copper.

Proteins are found in all living cells. Each species has its own specific proteins. When proteins are hydrolysed by enzymes, acids or alkalis, amino acids are produced. Over two hundred amino acids have been isolated from biological materials, but only 25 of these are generally regarded as being components of proteins.

Amino acids have a basic nitrogenous group, generally an amino group (- NH_2), and an acidic carboxyl unit (- COOH). The α type amino acids are the most frequently occurring ones. Their amino group is attached to the carbon atom adjacent to the carboxyl group.The general formula of the α type amino acids is shown on Figure 1.

Proline and hydroxyproline have an imino (NH) instead of an amino group. Some amino acids have additional amino and/or carboxyl groups.

Because of the presence of an amino and a carboxyl group, amino acids have both basic and acidic properties. In a strongly acid solution an amino acid exist largely as a cation, while in alkaline solution it occurs mainly as an anion.

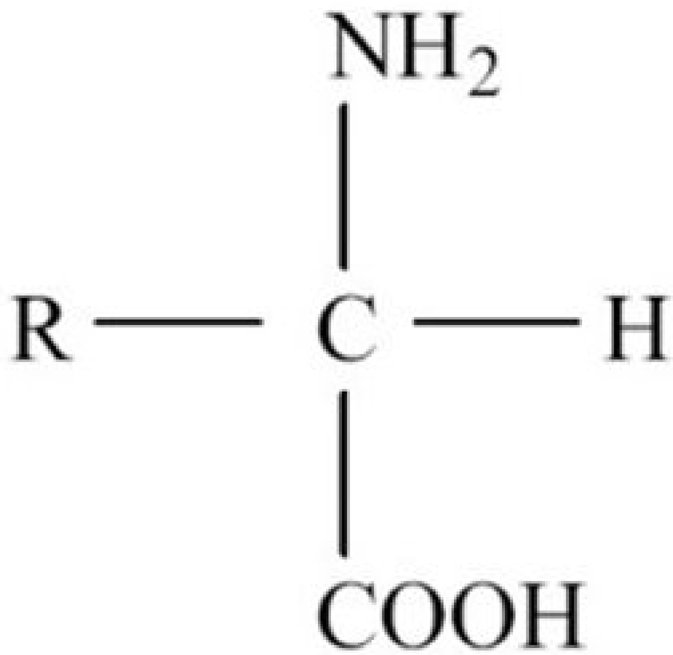

Figure 1: General formula of the α type amino acids

There is a pH value for a given amino acid at which it is electrically neutral; this value is known as the *isoelectric point*.

Amino acids act as buffers, resisting changes in pH. All the α-amino acids except glycine are optically active.

The nature of the ’R’ group varies with different amino acids. It may simply be a hydrogen atom as in glycine, of it may be, for example, a phenyl group.

All the amino acids involved in protein structure have an L-configuration of the carbon atom.

Plants and many micro-organisms are able to synthesize proteins from simple nitrogenous compounds such as nitrates. Animals, including humans, cannot synthesize the amino group, and in order to build up body proteins they must have a dietary source of amino acids. Certain amino acids can be produced from others by a process known as *transamination*, but a number cannot be effectively synthesized in the human and animal body and these are referred to as *indispensable* or *essential amino acids*. The ten essential amino acids that were determined using rats fed on purified diets are the following:

Arginine	Methionine
Histidine	Phenylalanine
Isoleucine	Threonine
Leucine	Tryptophan
Lysine	Valine

1.2 Structure and properties of proteins

Proteins are built up from amino acids by means of *peptide linkage* between the α-carboxyl of one amino acid and the α-amino group of another acid. In the example shown on Figure 2, a dipeptide has been produced from two amino acids. Large number of amino acids can be joined together by this means with the elimination of one molecule of water at each linkage to produce polypeptides.

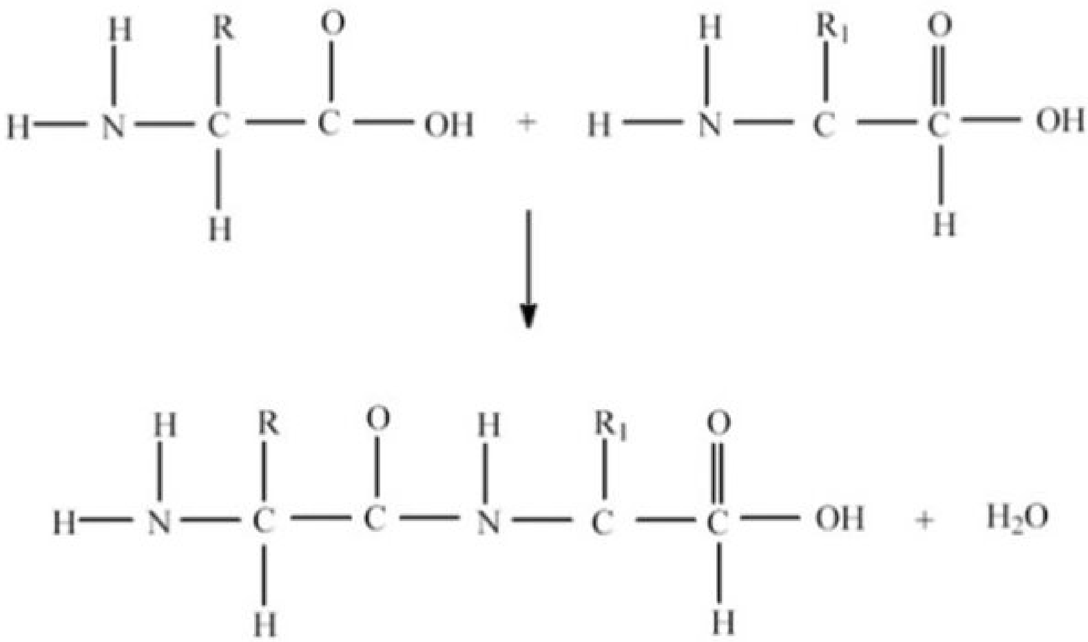

Figure 2: Formation of a dipeptide from two amino acids

Proteins have multiple levels of structure. The most basic is its *primary structure* which refers to the sequence of amino acids along the polypeptide chains of protein. Protein *secondary structure* refers to certain common repeating structures found in proteins. There are two types of secondary structures: alpha-helix and beta-pleated sheet. An alfa-helix is a tight helix formed out of the polypeptide chain. The polypeptide main chain makes up the central structure, and the side chains extend out and away from the helix. The carbonyl (CO) group of one amino acid (n) is hydrogen bonded to the imido (NH) group of the amino acid four residues away (n + 4). In this way every CO and NH group of the backbone is hydrogen bonded. The peptide chain exists in the form of a right-handed α-helix, which is coiled or folded, thus giving a rigid structure to the molecule. *Tertiary structure* is the full 3-dimensional folded structure of the polypeptide chain. This structure is belived to be mainly responsible for the specific catalytic properties of many proteins. The *quaternary structure* refers to the polymerized structures. It is only present if there is more than one polypeptide chain. For example, phosphorylase *a* containes four subunits (monomers) which alone have no enzymatic activity but when joined together (as a tetramer) form the active enzyme.

Most proteins have molecular weights varying from 20 000 to 200 000.
All proteins have colloidal properties; they differ in their solubility in water. They exibit characteristic isoelectric points, and have buffering properties. All proteins can be *denatured*. The most notable effects of denaturation are the changes in biological properties; for example enzymes are usually inactivated. Changes in solubility and optical activity may also occur.

Proteins may be classified into three main groups according to their shape, solubility and chemical composition.

Fibrous proteins	collagens, elastin, keratins
Globular proteins	albumins, globulins, histones, protamines
Conjugated proteins	phosphoproteins, glycoproteins, lipoproteins, chromo-proteins, nucleoproteins

Storage proteins were historically named after the plants from which they were isolated.
A considerable variety of nitrogenous compounds which are not classed as proteins occur in plants and animals. Amino acids form the main part of the non-protein nitrogenous fraction in plants, and those present in greatest amounts include glutamic acid, aspartic acid, alanine, serine, glycine and proline. Other compounds are nitrogenous lipids, amines, amides, purines, pyrimidines, nitrates and alkaloids.

Amines are basic compounds present in small amounts in most plant and animal tissues. Many occur as decomposition products in decaying organic matter and have toxic properties. Amines are produced by decarboxylation of amino acids. For example cadaverine is an amine formed from the amino acid lysine.
Asparagine and glutamine are important *amide* derivatives of the amino acids, aspartic acid and glutamic acid.

Nitrates may be present in plant materials. Quite high levels of nitrate were found in herbage given heavy dressings of nitrogenous fertilizers. *Alkaloids* occur only in certain plants, and are of particular interest since many of them have poisonous properties. Their presence is restricted to a few orders in the dicotyledons. For example, morphine is present in the dried latex of opium poppy. Solanin can be found in unripe potatoes and in potato sprouts.

-
-
-

Bibliography

Adams, M.W. (1973): *In* „Nutritional improvement of food legumes by breeding", PAG, UN, New York, pp 143-152.

Balaravi, S.P., - Bansal, H.C., - Eggum, B.O., - Bhaskaran, S. (1976). J.Sci. Fd. Agric. 27:545-552

Coates, J.B., - Medeiros, J.S., - Thanh, V.H., - Nielsen, N.C. (1985): Characterization of the subunits of *β*-conglycinin. Arch. Biochem. Biophys 243:184-194.

Frey, K.J. (1973):Improvement of quantity and quality of cereal grain protein. *In alternative sources of protein for animal production.* Nat. Acad. Sci., Washington, D.C. pp. 9-41.

Hajós-Novák, M., - Sipos, T., - Kőrösi, F. (2001/a): Mutants obtained by chronic gamma irradiation of soybean [*Glycine max*. (L.) Merrill] varieties. Proceedings, Third International Symposium on Nuclear and Related Techniques. October 22-26, 2001 Havana, Cuba. CD edition. pp 1-11.

Hajós-Novák, M., - Wágner, L., - Kőrösi, F. (2001/b): Economical value of soybean [*Glycine max*. (L.) Merrill] lines with high protein content. Proceedings of the 2nd Plant Production Conference, Budapest, pp 121-127.

Imsande, J. (2001): Selection of soybean mutants with increased concentrations of seed methionine and cysteine. Crop Scci. 41:510-515.

Janick, J. (2001): New crops for the 21st Century. In Nösberger, J.,- Geiger, H.H., - Struik, P.C. (Ed.) Crop Science: Progress and Prospects, CABI Publishing, pp 307-327.

Kitamura, K. (1995): Genetic improvement of nutritional and food processing quality in soybean. JARQ 29:1-8.

Køi, B., - Doll, H. (1979). *In* „Seed protein improvement in cereals and grain legumes", International Atomic Energy Agency, Vienna, 1:205-214.

Munck, L., - Bang-Olsen, K., - Stilling, B. (1985): Genome adjustment of by breeding to balance yield defects in high-lysine mutants of barley. *Int. Symp. Eucarpia, Genet. Manipulation in Plant Breeding.* September 8-13, 1985. Berlin, West germany

Ogawa, T., - Tayama, E., - Kitamura, K., - Kaizuma, N. (1989): Genetic improvement of seed storage proteins using three variant alleles of 7S globulin subunits in soybean (*Glycine max* L.). Japan . J. Breed. 39:137-147

Osborne, T. B. (1924): The Vegetable Proteins. 2nd ed. Logmans Green & Co., London, p 154.

Paek, N.C., - Imsande, J., - Shoemaker, R.C., - Shibles, R. (1997): Nutritional control of soybean seed storage protein. Crop Sci. 37:498-503.

Peterson, D. M. (1976): Protein concentration, concentration of protein fractions, and amino acid balance in oats. Crop Sci 16:663-66

Righetty, P.G., - Gianazza, E., - Viotti, A., - Soave, C. (1977): Heterogeneity of Storage Proteins in Maize. Planta 136:115-123

Biographical Sketch

Name: Dr. Márta Novák-Hajós
Date and place of birth: 21.06.1949. Kecskemét, Hungary
Marital status: married with one child
Home address: Kör u.8. II/7. H-2100 Gödöllő, Hungay
Home phone: (36-20) 313 40 86
Office: Department of Genetics and Plant Breeding, Gödöllő Szent Istvan University
Office address: P.O. Box 303, H-2103 Gödöllő, Hungary
Office phone/fax: (36-28) 522 069

EDUCATION AND QUALIFICATION

1967-1972 Gödöllő Agricultural University, Faculty of Agricultural Sciences
1972 MSc Agricultural Sciences
1975 MSc Genetics and Plant Breeding
1976 University doctoral degree
Ph.D. biology
1998 Habilitation in plant breeding

WORK EXPERIENCE

1972-1980 Research worker at Department of Genetics and Plant Breeding
1981-1984 Ph.D. student at Department of Genetics of Eötvös Loránd University, Budapest, Hungary
Supervisor: Dr. Gábor Vida Ph.D., DSc., Memeber of Hungarian Academy of Sciences

1985-1987 Research worker at Gödöllő Agricultural University
1988-1989 Senior Lecturer in Classical Genetics and Plant Breeding
1990- Associate Professor - Lecturer in Plant Breeding

RESEARCH ACTIVITIES

1972-1978 National research program on 'Biological consequences of applying chemicals'. The genetic effect of applying chemicals and mineral nutritions with normal and high doses on corn and pea plants.
1978-1990 National research program on 'Development of crop production'. Developing corn inbred lines and hybrids, variety maintenance. Development of methods to produce breeding stock in corn. Isozymes studies on diploid and autotetraploid corn. Study on regulation of *Adh1* gene in corn.
1992- Molecular markers (isozymes, RFLPs and RAPDs) in tetraploid corn breeding. (This program is supported by the National Scientific Research Foundation).
1995- Breeding for earliness and seed quality in soybean by induced mutation. RCM on „Improvement of new and traditional industrial crops by induced mutations and related biotechnology”(supported by the FAO/IAEA Vienna, No. 312.D2.RC.578.3).
2002- Application of molecular markers in poppy and grape variety protection.