The Role of Proteins in Animal Nutrition*

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THE term protein was first coined by Moulder, a Dutch chemist, in 1839 from the Greek word "proteios" meaning of primary importance. It was not until 1866 that Pettenkofer and Voit reported that protein performed a biological function in the animal body other than serving as a source of energy. In 1872 Carl Voit reported that proteins differed in their biological or nutritional value. He observed that gelatin would not take the place of meat in the ration of the dog.

Proteins of Minor Significance to Ruminants

It is rather elementary to say that proteins are essential to all life, both animal and plant. They are an essential part of the protoplasm in all cells. Plants are capable of synthesizing or creating protein for the animal kingdom. Some of the members of the animal kingdom, namely the ruminants are capable of synthesizing proteins from simpler nitrogen-containing compounds. To cattle and sheep, the source and form of nitrogen or protein is not as important as it is to the pig and chicken. Animals with rumens or multiple stomachs get along quite well on urea or inferior vegetable proteins and carbohydrates for growth, reproduction and milk production. They possess the unique ability of transforming the nitrogen from urea into amino acids and proteins into meat and milk. This ability in the rumens is explained on the basis that in the rumen are microorganisms which use the urea nitrogen, or inorganic nitrogen, or nitrogen from inferior proteins and synthesize amino acids and probably combinations of amino acids essential for animals with small stomachs.

Biological Value Important to Monogastric Animals

Cattle and sheep produce meat and milk on rations which would be nutritionally inadequate for chickens, pigs, or turkeys. In nutrition of swine and poultry, we speak of the biological or growth promoting value of a protein. This term has little or no significance in the nutrition of ruminants. The successful nutrition of cattle and sheep is primarily concerned with sources of available energy, nitrogen, fat soluble vitamins, and inorganic elements. In early life, the calf is like the non-ruminants in that the rumen is undeveloped and not functioning and hence it requires a better quality protein in early life. Nature made provision for this when she provided mammary glands on the females to secrete milk to nourish the young until the rumen was sufficiently developed to support life with simpler rations such as grass and grain.

The adequate or successful nutrition of single stomach animals or monogastric creatures is vitally concerned with proteins of proper biological or nutritional value. This discussion will deal primarily with the role of proteins in the nutrition of these animals.

Proteins in animals are a primary constituent of all body tissues and fluids, such as hair, skin, fur, muscles, bones, vital organs, blood and other body fluids, and enzymes. Proteins cannot be stored in depots for future use like the fats and hence they are required at regular short time intervals for body maintenance and for rebuilding body tissues worn out by regular activity. Any surplus or excess protein is deaminated and used as a source of energy by the animal. For adequate nutrition it is therefore necessary that the animals be supplied a specific amount of protein every day for normal body functions. Each animal requires a definite minimum amount of protein daily for optimum health and well being or for supplying certain definite chemical compounds. This has been best demonstrated on the human and probably more is known about the daily protein requirements of the human than any other species. The knowledge of the quantitative daily requirements of the single stomach animals for proteins is still limited.

The quantitative requirement for cattle has been established and is taken into consideration in the planning of rations for lactating or milking cows. The recommended allowances of digestible protein for dairy cows has been published by a committee on Animal Nutrition of the National Research Council (1) and these vary according to the weight of the individual. As an illustration, the recommended allowances for a 1,000-pound cow for maintenance is .6 of a pound of digestible protein. For pregnancy during the last 6 to 12 weeks, it is given as 1.2 pounds, and for each pound of 3% milk, it is given as .04 pounds. The source or origin of this protein for cattle is primarily from roughages and vegetable proteins.

The recommended protein allowance for beef cattle is also published by a sub-committee on beef cattle of the committee on Animal Nutrition of the National Research Council (2). These committees have for their membership men from the Agricultural Experiment Stations who are considered the leading authorities in their respective fields. The daily requirement of digestible protein for a 1,000-pound beef cow during the winter is given as .9 pound per day. There are numerous other recommendations for beef cattle depending upon the individual and the state of development and sex.

The knowledge of the quantitative daily requirement of small animals is not as well known. Since these creatures usually eat all mash or concentrated rations, the protein requirement is usually stated in terms of definite parts or percentage of the ration. The nutrition of small stomached animals is concerned with amino acid nutrition or similar compounds rather than with protein. Protein as such, is unimportant to these animals because the proteins are primarily carriers of simpler compounds which are amino acids or combinations of amino acids which are important in the nutrition of these animals. The protein materials available for feeding small stomached animals are composed of various compositions of amino acids and the nutritive value of any single protein or a combination of proteins is thought to be based on the amino acid composition and especially the presence of certain vital essential or indispensable amino acids. The amino acids are organic compounds which contain amino or NH_2 groups, and are divided

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into two classes namely, the essential and non-essential, depending upon whether they are required preformed in the ration of the rat and other animals like the chick or pig.

Amino Acids

This division or classification of the amino acids is based upon research by Rose (3) with the laboratory rat. The following are considered as essential for the rat—arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophane, and valine.

It has been found that the growing rat can grow to a slight degree without arginine but for maximum growth a definite amount of this compound is required in the ration.

Due to the high cost of synthetic or purified amino acids, research work on the amino acids has been limited. There have been several places where a considerable amount of fundamental work has been done in this field. Rose, of the University of Illinois, has worked on rats and humans with purified amino acids in synthetic rations. Holt (4) at Johns Hopkins has reported work on humans. Almquist (5), while at the University of California, did the pioneering work with chicks and has reported a classification of the amino acid requirements of chicks as follows: required for growth and maintenance—arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophane, and valine.

It has been reported by Almquist (6) that the following amino acids are required by chicks under certain conditions—cystine, glutamic acid, glycine, and tyrosine. The following amino acids are not required by the chick and may be absent from the diet without injury to the chick—alanine, aspartic acid, hydroxyproline and serine.

It has been reported that rats do not require glycine but chicks, when fed on similar purified or synthetic rations, develop a deficiency syndrome characterized by subnormal growth, improper muscular development and paralysis, and inferior feather development. Turkey poults however, show no signs of glycine deficiency when fed on a ration which produces this deficiency in chicks.

Based on work by Almquist and others, the subcommittee on Poultry Nutrition of the Nutrition Research Council (7) have recommended the following allowances of amino acids per pound of feed in the ration of growing chicks:

	Gms.
Glycine	4.5
Arginine	4.5
Methionine	4.5
Methionine*	2.7
Cystine	1.8
Lysine	4.1

* Minimum level of methionine should be 2.7 gms. with sum of cystine and methionine 4.5 gms.

Eventually as we learn more about the nutritional requirements of growing chicks and growing turkeys and when amino acids become lower in cost, there will be available information on the quantitative requirements in the ration for everyone of the essential amino acids.

The amino acid requirements of chicks and the role of these compounds in the nutrition of poultry is an unsolved problem and requires considerable work in the future. It has been observed that cystine can replace part of the methionine, but not entirely.. Formerly, cystine was considered an essential amino acid but it has been found out that methionine can completely replace cystine, but cystine cannot be entirely substituted for methionine.

Homocystine will replace methionine in the chick when sufficient choline is present in the diet. There is an interesting relationship among methionine, cystine, homocystine, and choline.

In recent years information has been obtained on some of the amino acids in the animal body. It has been observed on human males, that the amino acid arginine seems to be necessary for the production of sperm cells in the adults. There have also been reports that amino acid mixtures and protein hydrolysates are important in the building up of anti-bodies and hemoglobin.

A relationship between nicotinic acid and tryptophane has been observed. On rations high in corn, dogs and swine develop characteristic symptoms of niacin deficiency which can be alleviated through the administration or feeding of tryptophane. It has also been reported that the quantity of protein in the ration of the pig is related to the niacin requirement (8). When the protein content of a diet was low in some swine experimental rations made up of 10% casein and nicotinic acid omitted from the diet, the growth was impaired, associated with rough coat, diarrhea, poor appetite and severe anemia. Pigs of the same age and quality fed on a similar ration but containing higher protein showed no signs of any nutritional deficiency. This indicates a nutritional relationship between the amount of protein in the ration and nicotinic acid. It may be possible that some previously reported niacin deficiencies or syndromes of pellagra may have been complicated with tryptophane deficiency or tryptophane is required by the microorganisms of the alimentary tract for the synthesis of niacin.

Progress is now being made in the development of accurate methods for the measurement of amino acids in animal feeds. The newer techniques are being standardized which are resulting in quite accurate measurement of these compounds in complex mixtures. Amino acids are now being measured by chemical and microbiological methods. One of the primary problems associated with amino acid measurement is the hydrolysis of the protein to release the amino acids in such a way that they can be measured.

Many laboratories are working on this problem. The time is probably not very far hence when amino acids will be measured in animal feeds with as great accuracy and regularity as some of the vitamins are at present time. When these methods are standardized and the synthetic amino acids become available at low cost, progress on the quantitative requirement of amino acids for all single stomach animals will be very rapid and the vogue of referring to an animal's protein requirements will be obsolete.

The more practical way of satisfying the animal's protein requirements today is by determining and studying the amino acid composition of the various protein sources available for feeding and then making suitable combinations of these so as to satisfy the animal's requirements.

It has been announced by Almquist (9) that during the first two weeks of life the protein content of the rations should be higher than we had thought of in the past. The protein requirement of the chick has been thought to be between 19% and 22%. Almquist has recommended that for most rapid and ideal growth the chick startin~ ration should be 30% during the first two weeks.

The sources of protein available for baby chick feeding at the present time are the cereal grains which contain from 9% to 14% protein, which as single sources are totally inadequate in that they are deficient in three essential amino acids which are tryptophane, methionine, and lysine. These cereal grains are being supplemented with vegetable protein such as soybean meal, cottonseed meal, corn gluten meal, linseed meal, and others. The vegetable proteins, however, do not produce maximum growth in the young chick and need to be supplemented with a good source of animal protein such as fish meal, meat meal, or fish solubles. The prevailing thought is that these animal by-products contain amino acids lacking in vegetable oil meal. In studying the amino acid composition table and comparing the amino acids in oil meals with those in fish meal, the difference is not very great and does not give an entirely satisfactory explanation for the differences in growth observed between rations which contain animal proteins and those which do not contain animal protein. It has been reported that soybean oil meal properly processed is almost a complete and adequate source of protein except for its methionine content. If this is true then it should be possible to add some synthetic methionine content. If this is true then it should be possible to add same synthetic methionine to a soybean oil meal ration. This has been done, and with a few Leghorn chicks it has been possible to get growth equivalent to that produced by fish meal but with heavy breed chickens such as the Crossbred or White Rocks this has not been possible. Patton and co-workers (10) recently reported that methionine will not replace sardine meal in a corn-soybean oil meal ration.

Recently a new compound has been reported and referred to as strepogenin by Woolley (11). He worked with mice and observed that when he fed a pure synthetic ration containing all the nutrients required by mice, it did not produce as good a growth as mice on a similar ration in which the amino acids were supplied in the form of a protein hydrolysate. He explained this difference in growth on the basis that the amino acids as such in synthetic form could not adequately satisfy the nutritional requirements of the growing mouse, but that these animals required a simple combination of amino acids or peptides, to adequately satisfy their requirements for growth. This may be an explanation for the nutritional value of animal by-products such as fish, meat and milk to supplement vegetable oil meal proteins in the feeding of the growing chick and pig.

The protein requirement for growing chicks from six weeks of age to twenty weeks of age is considered as being between 16% and 18% of the total ration and the requirements for animal protein is considered less than for rapid growth in early life.

The protein requirement of breeders and layers for egg production is considered to be approximately 15% of the total ration and can be made up largely of vegetable oil meal and cereal proteins but for maximum hatchability it has been observed that a small amount of animal protein is required. This has been referred to in the last few years as the "animal protein factor." There is a feeling among poultry nutritionists that there is a special nutrient probably different from simple amino acids, in fish meal, fish solubles, and other animal by-products, which they refer to as the "animal protein factor." This factor has not yet been isolated in pure form and hence nothing is known of its chemical nature.

Workers at the U.S.D.A. at Beltsville (12) have observed that dried cattle manure has the same nutritional property. There is a nutrient or a combination of nutrients or compounds in dried cattle manure which can supplement vegetable oil meals as well as animal by-products. This is true for hatchability, rapid growth, and chick liveability. This factor is insoluble in fat solvents and only partially soluble in water and other aqueous solvents.

The oil meal proteins are excellent sources of protein but when fed in high levels seem to have a physiological effect in the chick which causes the droppings to be abnormally sticky. This is especially true of linseed oil meal.

Less is known about the protein requirement of turkeys, ducks, and pheasants than about chickens. It has been observed however, that the protein requirements of turkeys are considerably higher than they are for chickens for maximum growth. Qualitatively they are somewhat similar. Feeding growing turkeys on rations high in peanut oil meal causes a lack of pigment in the dark feathers. Feeding soybean meal and peanut meal side by side to turkeys, it is observed that the turkeys on the peanut oil meal ration will have normally pigmented feathers. Fritz (13) and co-workers have just reported that a lack of lysine causes a lack of pigmentation and that 1.1% to 1.2% of lysine is required in the turkey diet for normal feather pigmentation. Peanut oil meal furnishes only about half as much lysine as soybean oil meal. The protein requirement of turkey poults for growth is considered to be about 25% of the total ration. For layers and breeders it is considered to be 16% to 18%. There are still unsolved problems in turkey nutrition which are related to normal feathering, normal skin condition, and leg development.

The protein requirement for ducks is generally taken to be 20% to 25% of the total ration for growth, and approximately 15% for layers and breeders.

Much research has been conducted on swine nutrition but the work has been very much of a practical nature and the fundamental study is somewhat limited. The leaders in this field have been Ellis of the U.S.D.A., Wintrobe now at the University of Utah, and Krider of the University of Illinois. The protein requirement for growth from 35 to 125 pounds is considered to be 18% of the total ration. The sources of protein in swine growing rations have been soybean oil meal, cottonseed meal, linseed meal, and tankage. Tankage seems to have a peculiar nutritional value for swine which it does not display for poultry. Tankage and meat meal for poultry do not rank with fish meal to supplement vegetable protein. Tankage and vegetable oil meals are not the most potent combinations for swine. A combination of these ingredients is also improved by fish meal or fish solubles. Toward the end of the fattening period, the protein required both quantitatively and qualitatively decreases for swine. The last 75 to 100 pounds can be made quite effectively and satisfactorily on low protein rations of inferior quality.

The recommendations for the daily protein allowances for swine as given by the Nutrition Research Council (14) are as follows:

.6 pound of crude protein per day for a 50-lb. pig
.8 pound of crude protein per day for a 100-lb. pig
.9 pound of crude protein per day for a 150-lb. pig
1.0 pound of crude protein per day for growing and fattening pigs over 200 lbs. body weight.

For pregnant females and young boars .9 lb. per day of crude protein are recommended and for lactating sows 1.5 to 2.3 lbs. of protein per day.

The protein requirements of dogs, fox, and mink have not received very much study in the past. Their requirements, however, have probably been met very satisfactorily through the feeding of large quantities of raw meat. Fox and mink are fed from 45% to 85% of the total ration as raw meat, which usually consists of raw horse muscle meat. The future for the fox and mink as being able to obtain sufficient raw meat in the future is not very bright. Due to the rapid decrease in the horse population in the country during the last twenty years, it is entirely possible that within the next 10 to 15 years there will be little or no raw horse meat available for the feeding of these animals. It is, therefore, imperative that research be instituted on the qualitative and quantitative protein requirements of fox and mink to study other sources of protein for their nutrition.

Dogs can be fed satisfactorily generation after generation on rations which do not contain raw meat. It is possible to feed dogs for generation after generation on a completely dry ration in which the protein is composed of cereal products, vegetable oil meals, and dried animal products. This is not true of the fox and the mink. The protein requirement of dogs has never been established but excellent results have been obtained on rations which contain 22% protein from vegetable and animal sources.

The sources of protein for animal feeding come from the following: cereal grains, vegetable oil meals, and animal by-products. The cereal grains contain from 9% to 14% protein and furnish a very large proportion of the total protein in the ration of poultry and swine. In poultry rations the cereal grains supply from one-fourth to one-third of the total protein in the ration and when properly supplemented with proteins of better biological value they serve very well as a source of protein.

The vegetable oil meals contain from 30% to 47% protein and rank in the following order of importance in feeding: soybean oil meal, cottonseed oil meal, linseed oil meal, corn gluten meal, peanut oil meal, sesame meal, and sunflower meal.

The soybean oil meal production in the United States was 3,179,000 tons in 1942. A very large portion of this was used in animal feeding. Soybean oil meal is produced by three different methods which are the expeller process, solvent extracted, and hydraulic press. With proper heat treatment the soybean oil meal from all three processes is of equal nutritional value and soybean oil meal is usually considered to be superior to all the other vegetable oil meals as a source of protein for poultry and swine.

In the cold extraction of oil from soybeans it is necessary to heat or toast the meal to improve the nutritional value. It is still an unsettled question as to whether the heating makes the protein more digestible or more available or whether the heating destroys some toxic principle. There has been some work to indicate that raw untoasted soybean oil meal contains some globulins which are toxic to the animal or have a destructive effect on the digestive enzymes. Soybean oil meal will probably be the future primary supply of protein for swine and poultry. It can be grown over a wide acreage in the United States and fits well into the corn belt system of crop rotation.

Cottonseed meal has been generally considered as a protein for the feeding of dairy cattle and beef cattle and sheep, but it also has excellent feeding value for swine and poultry. This is especially true for growing chicks if the cottonseed meal has been properly processed. The nutritional value of this product is closely related to the method of processing. In the past, cottonseed meal has suffered some unfavorable publicity due to its being fed to swine and cattle in rations which were deficient in vitamin A. It was observed that cottonseed meal contained a pigment, gossypol, which is toxic to swine and poultry but at the levels ordinarily fed in practical rations, gossypol poisoning is no problem in the feeding of swine and poultry. Laying hens which were fed on rations containing cottonseed meal produced eggs which developed a peculiar mottled color of the yolks after being refrigerated. For this reason it is not recommended at the present time to use cottonseed meal in laying rations. The cottonseed meal produced in 1942 in the United States was 1,995,000 tons.

Linseed oil meal has enjoyed an excellent reputation for its nutritional value for the feeding of cattle and sheep. For poultry, the biological value of its protein is inferior to soybean and cottonseed, and only a rather limited amount can be fed because it produces a peculiar effect on the droppings. The production of linseed oil meal in the United States in 1942 was 790,000 tons, most of which was fed in cattle and sheep rations. It is the feeling among dairy men and beef cattle men that linseed oil meal has the peculiar property of producing an especially fine finish or glossy coat on the animal. It is the feeling of animal husbandry men that they can not get this finish with any other source of protein.

Peanut oil meal is not a very large factor in the feeding of farm animals. The peanut meal produced in the United States in 1942 was 54,000 tons. Peanut meal is at an economic disadvantage with other oil meals for animal feeding because of the present economics of producing peanuts and its superior nutritional value for human consumption and its inferior feeding value for animals.

Sesame meal has fine supplementary value to soybean oil meal. It contains more methionine than soybean meal and soybean meal contains more lysine than sesame meal and the two supplement each other very well. The amount of sesame oil meal for animal feeding is very limited since it has to be imported from foreign countries and it is not produced domestically.

Sunflower meal, according to Almquist, is the most complete protein of vegetable origin for the feeding of poultry. It is unfortunate that this meal is not produced in this country in sufficient quantities for animal feeding but must be imported from South America.

The animal protein sources which are required for the supplementing of the vegetable proteins are produced in insufficient quantities to adequately supplement the vegetable oil meals. The primary sources of animal protein are fish meal, which comes from two sources namely, sardine meal and menhaden meal; meat scrap, which is the by-product of the meat packing industry; and tankage, which is also a by-product of the meat packing industry. These products are not produced in sufficient quantities to adequately supplement the rations of single stomach animals and this is a challenge to the animal nutritionists to find other sources of the peculiar nutrient in these products to supplement cereal and vegetable proteins.

There have been various methods used for the evaluation of proteins for single stomach animals. These methods are all based upon animal feeding experiments which are time consuming and costly, but up to the present time, the only reliable method. A chemical method has been devised by Almquist which looks quite satisfactory for the evaluation and comparison of the nutritional value of proteins from meat and fish, but cannot be applied to proteins of vegetable origin.

The earlier methods have been based upon rat feeding studies, most prominent and well known of which is the Mitchell technique of measuring nitrogen retention. This method involves very accurate recording of feed intake and excretion and nitrogen determination. A simpler method used is the rat growth method in which the rats are fed a purified diet containing no protein from any other source except from the material being assayed. The rat's ration is adequate in all other nutrients except protein and the young newly weaned rat is fed 10% of protein from the material to be evaluated. This is fed for a period of 28 days and the growth recorded. This is a measure of the nutritional value of the protein as a complete source but not necessarily a measurement of its supplemental value. For supplemental value studies the chick is used. In this, the material to be studied is fed along with vegetable protein and the growth measured as compared with the same ration at the same protein level containing no animal protein. This gives a true measure of the ability of the protein to supplement soybean meal or other vegetable protein material but gives no information on what an animal's requirements are for any specific compound.

Other methods of evaluating the nutritional merits of proteins have been reported. One of which is the serum protein regeneration technique used by Cannon at the University of Chicago. This involves the use of rats which are fed, for a number of weeks, on a ration containing less than 2% protein until the serum protein content of the blood is subnormal. At this stage, the diet of the rat is supplemented with the protein to be investigated and fed for a period of 10 days to 2 weeks and then the serum protein content measured, and if it has been sufficiently increased the protein is considered to have good biological value. Other methods involving the use of dogs and rats have been used but all methods are time consuming and laborious.

The chemical or microbiological determination of amino acids and other protein-like compounds will eventually be developed which will give us rapid methods for measuring the nutritional value of proteins.

Summary

1. Proteins are an essential nutrient required for the proper nutrition of all animals.
2. The animal kingdom is dependent on the plant kingdom for the major portion of the protein.
3. The ruminants are not as specific in their protein requirements as the animals with small stomachs.
4. Proteins for monogastric animals are sources of undefined nutrients along with certain amino acids.
5. Biological value of proteins is an expression of the nutritional value of a protein for animals with small stomachs.
6. More information is required on the nutrients or compounds furnished by proteins of high biological value.
7. The animal proteins required to supplement vegetable proteins are available in insufficient quantities for the adequate nutrition of swine and poultry.
8. Better methods are needed for the proper evaluation of proteins.

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