# Nutritional Framework of Oilseed Proteins[1]

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## ABSTRACT

The nutrient composition of oilseeds is a variable property. The oilseed's genetics, growing environment, handling, storage and processing all present variables which may affect the nutrient composition and resultant nutritional value. How well an oilseed protein product achieves the desired use effect will depend on its inherent composition.

## INTRODUCTION

Oilseeds have been widely used in the past as a source of crude protein in animal and poultry rations. With the rapid expansion in usage of oilseeds as food ingredients, it has become necessary to examine critically the total nutrition supplied by these oilseed protein products. This presentation will discuss components of oilseeds and factors which affect their distribution. Components are emphasized since oilseeds contain both nutrients and factors which are not of nutritional value and in fact may even have adverse effects. The principal concept which will be stressed in this presentation is that the nutrient composition of oilseed products is a variable property affected by many physical and chemical factors. Such factors as location and environment under which the oilseed is produced, varietal genetics, seed treatment prior to processing, and processing conditions all have significant influences on the nutrient composition of the final product. Each of these factors will have to be carefully considered if oilseed products are to have maximum influence on nutrition.

It is acknowledged that currently oilseed proteins are included in food products not principally for their nutritional value but for the functional properties they impart. This paper will not discuss the nutritional aspects of functionality, mainly because our knowledge of oilseed proteins has not advanced to the stage where all the many interrelationships between nutrient composition of the oilseed and its inherent functionality are known. It should be pointed out however that the functional properties of an oilseed product have to be related closely to its composition and those factors which alter the nutrient composition.

The oilseeds will be grouped collectively since the basic factors which affect their influence on nutrition are similar. An example would be the conditions of heat denaturization of protein; the principle would be essentially the same whether the oilseed was soy, cottonseed, linseed, peanut, rape, castor, safflower or sunflower. Cottonseed will be used as a model in many of the examples because of data availability.

### Seed Structure and Composition

Oilseeds, like other plant seeds, may be considered as warehouses of stored nutrients which are intended for use in the germination process. The seed contains all of the food material required by the seed embryo for its initial development—the protein, carbohydrates, lipids, growth factors, enzyme systems and several minerals. When the seed embryo is exposed to the proper conditions of moisture and temperature the enzyme systems are activated and the phenomenon of growth takes place. Hydrolysis of stored protein takes place during germination and the resulting amino acids become raw material for the formation of new plant tissue.

The ultrastructure of oilseeds may be represented by that of cottonseed. The cells of the cottonseed may be divided into five areas (1): (a) the nucleus; (b) the spherosomes which contain the fat; (c) the protein bodies which contain the storage proteins and the phytin particles called globoids; (d) the cytoplasm in which these particles and other functional particulates are embedded; and (e) the cell walls.

Proteins serve three important functions in the seed. They are part of the structural element of the seed, such as the cell wall and various membranes; they are involved in the working machinery of the cell, the various enzyme and cell components which keep the cell vital; and they are part of the stored food which is so important during germination. As will be discussed later the protein concentration, amino acid composition, and solubility characteristics of the various proteins will vary significantly from function to function and from oilseed to oilseed.

It is important here to consider that the nutrient composition, nutritional value, and physical or functional properties of any resulting product from oilseeds will depend on how the cell components are separated and conditions employed during separation. The seed in its dormant state is the ultimate potential for the particular oilseed; processing conditions then determine the characteristics of the final product.

### Nutrient Composition

Differences in gross composition of selected oilseeds are presented in Table I. These data are important since they give some indication of the nutrient composition of the raw material to be processed into products for feed or food. The degree and type of processing may alter the analyses significantly, from full fat flour which will contain essentially the same amounts of each of the major classes of

[1]One of 21 papers presented at the Symposium, "Oilseed Processors Challenged by World Protein Need," ISF-AOCS World Congress, Chicago, September 1970.

TABLE I

Comparative Composition of Various Oilseeds (6)

| Analysis | Soybean | Cottonseed | Peanut | Flax | Safflower | Sesame | Sunflower[a] |
|---|---|---|---|---|---|---|---|
| Moisture | 10 | 7 | 5 | 6 | 7 | 8 | 6 |
| Protein (N x 6.25) | 38 | 23 | 30 | 24 | 16 | 22 | 19 |
| Lipids | 18 | 23 | 48 | 36 | 30 | 43 | 45 |
| Fiber | 5 | 17 | 3 | 6 | 27 | 10 | 16 |
| Ash | 5 | 4 | 2 | 4 | 3 | 6 | 3 |
| Nitrogen free extract | 24 | 26 | 12 | 24 | 17 | 11 | 11 |

[a]Reference—National Cottonseed Products Association, Inc. (1970), unpublished.

TABLE II

Comparative Amino Acid Patterns of Oilseed Meals (7)
(g/16 gN or % Protein)

| Amino acid | Meal from | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Soybean | Cottonseed | Peanut | Linseed | Safflower | Sesame | Sunflower | Castor |
| Arginine | 7.5 | 11.0 | 10.3 | 9.3 | 7.8 | 11.9 | 7.8 | 10.0 |
| Histidine | 2.5 | 2.7 | 2.2 | 1.8 | 2.0 | 2.2 | 2.2 | 1.7 |
| Isoleucine | 5.5 | 4.0 | 4.3 | 4.6 | 3.8 | 4.3 | 4.5 | 4.6 |
| Leucine | 7.7 | 6.2 | 6.7 | 6.0 | 5.5 | 6.9 | 6.0 | 5.6 |
| Lysine | 6.2 | 4.2 | 3.5 | 3.6 | 2.7 | 2.8 | 3.8 | 3.0 |
| Methionine | 1.4 | 1.5 | 1.0 | 1.7 | 1.5 | 2.6 | 2.2 | 1.5 |
| Phenylalanine | 4.9 | 5.2 | 5.0 | 4.5 | 5.2 | 4.7 | 5.1 | 4.7 |
| Threonine | 4.0 | 3.5 | 3.0 | 3.8 | 2.9 | 3.6 | 3.4 | 3.2 |
| Tryptophan | 1.7 | 1.6 | 1.2 | 1.7 | 1.2 | 1.9 | 1.4 | 1.1 |
| Valine | 5.4 | 5.0 | 4.8 | 5.6 | 4.9 | 5.1 | 4.9 | 5.4 |

nutrients as did the raw material, to the sophisticated production of protein isolates which will contain in excess of 95% crude protein (N x 6.25) on a dry weight basis, 2-4% ash, and traces of other compounds.

It is interesting to note in this table that these diverse oilseeds have much in common in their gross analyses; the principal exception is the soybean and its high protein - oil ratio. These data support nicely the relative importance of oil in oilseed processing, the exception being soybean which because of its high protein content is often crushed with emphasis on the protein depending on the current marketing conditions.

Table II presents the average amino acid content of several oilseed proteins. Differences may be noted between the proteins. The significance of these differences is often difficult to evaluate since seldom, if ever, would the protein source be fed alone. In practical rations or diets where the protein requirement is met by a combination of protein sources, the complementary effects of other ingredients often supply needed amounts of the critical amino acids to meet dietary requirements. In most cereal grain-oilseed based rations the two amino acids most often limited are lysine and methionine. Both of these amino acids are commercially available and may be used to supplement existing deficiencies. Therefore the amino acid pattern of an oilseed does not have the importance today that it did a few years ago. Production economics and functionality of the various oilseed sources take on increased emphasis.

## Environmental Effects

Environmental conditions often affect the nutrient composition of oilseeds and influence product characteristics. Weather conditions together with soil fertility and possibly other factors have considerable influence on the characteristics of oilseeds. The most notable examples are variation in protein content of soybeans, fatty acid patterns of sunflowers, and gossypol content of cottonseed between geographical locations. Therefore the potential of an oilseed could be influenced by outside factors.

## Genetic Effects

Varietal genetic changes in the oilseed may influence its potential usage. There are several examples where, through selective breeding, new varieties have been produced which open new end product possibilities. Such examples are a high protein variety of soybeans, erucic acid free rapeseed, thin hull and high oleic safflowers, high oil sunflowers, and cottonseeds bred void of pigment glands which contain the gossypol. These examples show the potential for "tailor making" oilseeds which will be more ideally suited as raw materials.

## Storage Effects

The nutrient composition of oilseed products may be affected by conditions of seed storage. Seed moisture levels, storage temperatures, and length of storage have been shown to alter composition. Since there are active enzyme systems present in the stored seed, it is not surprising that with time and proper environmental conditions the lipases start to break down lipids with resulting free fatty acid buildup and the proteases start to catabolize the proteins. Even the simple moisture loss in seed during storage necessitates processing procedural changes. With the more sophisticated methods of processing which are demanded in

TABLE III

Composition and Yield of Cottonseed Protein Concentrates (2)

| Analysis | Method of preparation | | |
|---|---|---|---|
| | | Aqueous extraction | |
| | Air classification | 90% Ethanol | .008 M $CaCl_2$ $H_2O$ |
| Composition - %[a] | | | |
| Protein (N x 6.25) | 73.7 | 71.9 | 75.9 |
| Lipid | 0.7 | 0.1 | 2.6 |
| Ash | 9.4 | 8.7 | 8.5 |
| Crude fiber | 1.7 | 2.7 | 3.7 |
| Total sugar (As invert) | 4.7 | 2.1 | 0.3 |
| Yield[b] | | | |
| Total weight, % | 56 | 84 | 60 |
| Total nitrogen, % | 63 | 93 | 77 |

[a]Dry weight basis.
[b]"As is" basis.

TABLE IV

Proximate and Amino Acid Composition of Glandless Cottonseed Flour and Isolates (2)

| | | Isolates | | |
|---|---|---|---|---|
| | | Classical method | Selective extraction | |
| Analysis | Flour | FP[a] and SP[b] | FP[c] | SP |
| Composition - %[d] | | | | |
| Nitrogen | 10.73 | 15.58 | 13.08 | 17.24 |
| Crude fiber | 2.2 | 0.5 | 0.5 | 0.2 |
| Lipid | 0.9 | 1.1 | 3.0 | 0.2 |
| Ash | 7.8 | 3.4 | 14.1 | 1.0 |
| Phosphorus | 2.19 | 0.69 | 3.13 | 0.26 |
| Total sugar | 7.3 | 0.5 | 0.5 | 0.0 |
| Amino acid - g/16 gN | | | | |
| Lysine | 4.4 | 3.4 | 6.0 | 3.0 |
| Histidine | 2.9 | 2.9 | 2.6 | 3.0 |
| Arginine | 12.4 | 10.0 | 10.4 | 11.3 |
| Aspartic | 9.1 | 9.0 | 6.7 | 8.4 |
| Threonine | 3.0 | 2.9 | 2.9 | 2.7 |
| Serine | 4.1 | 4.0 | 3.4 | 4.5 |
| Glutamic | 20.4 | 16.4 | 21.8 | 18.9 |
| Proline | 3.6 | 3.4 | 3.1 | 3.1 |
| Glycine | 4.1 | 3.5 | 3.2 | 3.7 |
| Alanine | 3.7 | 3.6 | 3.2 | 3.5 |
| Valine | 4.6 | 4.7 | 3.3 | 4.4 |
| 1/2 Cystine | — | — | 2.6 | 0.3 |
| Methionine | 1.3 | 1.4 | 1.7 | 1.0 |
| Isoleucine | 3.4 | 3.4 | 2.6 | 3.1 |
| Leucine | 5.8 | 5.7 | 5.1 | 5.8 |
| Tyrosine | 3.1 | 2.8 | 3.3 | 2.6 |
| Phenylalanine | 5.5 | 5.7 | 3.7 | 6.3 |

[a]FP, functional protein.
[b]SP, storage protein.
[c]Neutralized.
[d]Dry weight basis.

the production of concentrates and isolates, the effects of storage and conditioning become increasingly important if the true potentials of the oilseed are to be realized.

## Processing Influences

The final nutrient composition of the oilseed products is determined by the type and extent of processing. We can think of processing simply as a systematic method of changing the composition or characteristics of the seed to the product desired. If soybeans are simply dehulled, heat treated, and ground, a *full fat flour* is produced. A feed grade soybean or cottonseed *meal* is produced by extraction of lipid material and removal of a portion of the crude fiber. The production of a *flour* containing 50-60% protein is simply the upgrading of meal under sanitary conditions. Further upgrading results in *protein concentrates* which are protein products containing 65-70% protein. Concentrates may be prepared principally by two methods. These are a wet method consisting of alcohol or water leaching of the defatted flakes, or liquid classification, and a dry method involving air classification. *Protein isolates* are essentially "pure" protein sources produced by a sophisticated series of extractions. The isolates are prepared from flakes or flour which have had minimal exposure to moist heat in order to retain maximum protein dispersibility. The protein is solubilized in an aqueous medium and is separated from the fibrous seed residue by various screening, filtering and centrifuging devices. The pH of the clarified extract is then adjusted with food grade acid to precipitate the major proteins.

The heat and moisture conditions of processing have a significant effect on the final product characteristics. Excessive heat will congeal the cytoplasmic proteins into a nondescript mass, thereby eliminating the opportunity to selectively separate these proteins during protein concentration or isolation. Severe heat treatment results in the destruction of several amino acids, particularly lysine, methionine, arginine, tryptophan and cystine. Not only does the destroyed or inactivated amino acid affect the amino acid profile of the protein, it probably has a significant effect on the availability and utilization of the other amino acids. The influence on nutritional value of the resulting product is readily apparent.

The method of processing and its effect on nutrient composition of the final product may be observed in the production of cottonseed protein concentrates. With a properly defatted glandless flour, one in which the protein bodies are not "glued" in place by denaturing the cytoplasmic proteins, protein concentrates may be produced by air classification or by aqueous extraction procedures (2).

As shown in Table III these cottonseed protein concentrates provide a broad range in protein and cellular composition. The air-classified concentrate is very low in cell wall fragments but contains some sugars and both the cytoplasmic or functional proteins and the storage proteins. Extraction with dilute calcium chloride followed by a water wash will remove sugars, color and flavor components, and the low molecular weight water soluble proteins, and results in an extracted concentrate which is very high in cell wall fragments and intact protein bodies. Leaching with 90% ethanol removes residual lipids and some sugars but only a minimum of nitrogen. The alcohol-leached product is intermediate in composition compared to the other two processes. The cottonseed therefore offers the potential of three concentrates which are similar in nitrogen content but differ in protein and nonprotein composition depending on the processing method involved.

Another striking example of how the type of processing directly affects the nutrient composition and potential use of the product is in the production of cottonseed protein isolates. The protein bodies of the cottonseed, unlike those of the soybean and the peanut, do not rupture on suspension in water to produce a water dispersion of the storage proteins. Alkali or salt is needed to rupture the protein body membrane and to solubilize the storage proteins of the cottonseed (3). Based on these extraction characteristics the proteins of the cottonseed may be divided into two groups, water dispersible and water nondispersible. This division coincides with the cytological division. The water dispersible proteins are predominantly the functional proteins (FP) of the cytoplasm and the water nondispersible proteins are essentially the storage proteins (SP) of the protein bodies. The functional proteins are low in molecular weight with a sedimentation coefficient of 2 and many in number. The storage proteins are high in molecular weight with sedimentation coefficients of 7 and 12 and few in number. The two groups of proteins also differ in solubility characteristics. The functional proteins have a minimum solubility at pH 4 and the storage proteins are least soluble at pH 7. A combination of the two groups in the proportion found in the flour shows a minimum solubility at pH 5 (2). Methods for protein isolation have been devised on the basis of these distinct differences in extractability and solubility. These methods plus the classical procedure for isolate production (as used by the soy industry) provide flexibility in isolate production from cottonseed. The comparative nutrient composition of three cottonseed protein isolates is shown in Table IV.

With the selective extraction procedure the proteins are separated and two isolates are prepared (4). The FP isolate represents 11% of the weight and 16% of the nitrogen of the flour. The storage protein (SP) isolate comprises 30% of the weight and 53% of the nitrogen. Together they give essentially the same recovery of weight and nitrogen as the single step, classical procedure. However separately they provide two isolates which differ from each other and from the single step isolate in average molecular weight, in nonprotein nitrogen, protein, amino acid composition, and functionality.

### Anti-Nutritional Factors

No discussion of the nutrient composition of oilseeds would be complete without briefly covering the numerous factors present in oilseeds which have possible adverse effects on nutrition. For reasons still not completely understood many plants have the capacity to synthesize a wide variety of chemical compounds which are known to cause deleterious effects when ingested by man and animal. Oilseeds are not exempt for soybeans have a trypsin inhibitor, hemagglutinin, saponins, allergens, estrogens, goitrogens, and proteolytic enzymes; cottonseed has gossypol; rape and crambe have thioglucosides; castor beans have ricin. Allergens have been demonstrated in most oilseeds and may be considered possibly a common factor in all.

Mild heat treatment has been shown to be necessary for most oilseeds to maximize nutritional value and to inactivate the heat labile proteins responsible for the trypsin inhibition and hemagglutinin activities found in most legumes. Research at Louisiana State University (5) demonstrated that glandless cottonseed protein was more efficiently utilized by the chick after mild heat treatment. Therefore it could be concluded that in order for oilseeds to be utilized to the fullest degree they must be "properly" heat processed; the conditions of processing will depend on the inherent characteristics of the oilseed. As the market demand of oilseed proteins develops there will probably be more processing procedures developed to further reduce the relative importances of these naturally occurring factors.

In summary, the nutrient composition of oilseeds is a variable property. The oilseed's genetics, growing environment, handling, storage, and processing all present variables which may affect the nutrient composition and resultant nutritional value. There is no question as to the promise and potential of oilseeds in providing needed nutrients to the diets of man and animal. The potential is there; how well we achieve that potential is determined by how well we can preserve (or improve) the natural product by our handling and processing. The challenge is ours.

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