Functionality of Vegetable Proteins Other Than Soy

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ABSTRACT

In addition to the soybean, many other sources of vegetable protein have potential to provide a broad spectrum of functional properties. Among these sources are cottonseed, peanut, sunflower, and rapeseed. As with soy, the functional characteristics vary with the type of product, e.g., flour, concentrate, or isolate. In this discussion, functionality is defined as the set of properties that contributes to the desired color, flavor, texture , or nutritive value of a product. Utilization of these alternate sources of vegetable proteins will depend upon availability, economics of the product in any given country, and on the uniqueness and desirability of the functional properties of the product.

Functionality can be defined as the set of properties of a protein or protein ingredient that contributes to the desired color, flavor, texture, and nutritive value of a food (1). I draw your attention to two elements of this definition; one, the fact that the "... properties ... contribute ... ," the other, the fact that the characteristics to which they contribute are "desired." Under this definition, therefore, one is concerned not with the properties of the protein ingredient *per se,* but rather the manner in which the protein ingredient performs in the finished product.

The first three attributes of food products, namely color, flavor, and texture, are the major factors governing consumer acceptance. Currently, however, the fourth attribute, nutritive value, is assuming increased inportance from both the regulatory and consumer perspective.

The recorded contribution of vegetable protein products to desired color and flavor of food products is relatively limited. Most defatted oilseed flours provide improved crumb color in baked goods, presumably due to increased browning reaction between the oilseed proteins and carbohydrates (2, 3, 4). Also, the pigments of cottonseed flour are reported to enhance the yellow color of doughnuts (5). This lack of functionality in the areas of color and flavor is usually the direct result of a conscious attempt on the part of the vegetable protein processor to market an ingredient with minimum color and flavor. The objective is a protein ingredient with maximum versatility in the fabrication of extended or imitative foods. Sharp accents in either color or flavor will limit the utility of the ingredient. Users of vegetable protein products, therefore, must be equally concerned with both the functional and the qualifying characteristics of an ingredient, i.e., those properties that diminish rather than contribute to the desired attributes of a food.

Table I lists certain qualifying properties with respect to color, flavor, and nutritional quality that may be associated with vegetable protein products. The extent to which they are found in the commercial product (flour, concentrate, or isolate) will vary with the type and degree of processing. This table includes information on soybean products. Throughout this paper on vegetable proteins other than soy, equivalent information on soybean products will be provided where appropriate as a reference point.

All defatted vegetable protein products contain some level of residual plant pigments, usually polyphenols. Those associated with soybean and peanut do not contribute significantly or detrimentally to the color of most foods at current use levels. In certain end uses, the residual pigments of cottonseed, sunflower, and rapeseed will contribute to the color of a product sometimes positively, sometimes negatively.

Residual pigments of cottonseed protein products (7,

TABLE I

Qualifying Factors in Vegetable Proteins

Defatted oilseed flours	Color	Flavor	Antinutritional factors and limiting amino acid(s)
Cottonseed	Yes Yellow (5,6) Green	No Bland (5,6)	Gossypol (7) Lysine (8)
Peanut	No (9)	Yes Raw Cereal (9)	None (10) Methionine-Lysine (10)
Rapeseed	Yes Green (11) Brown	Yes Bitter Sulfurous (12,13) Musty	Glucosinolates (14,15) None (16,17)
Sunflower	Yes Green (18) Brown	Yes Bitter (18) Astringent	None (18) Lysine, Isoleucine (18)
Soybean	No (19)	Yes Beany (19,20) Bitter Grassy	Trypsin Inhibitor (21,22,23) Methonine (24,25,26) Methionine

27) can be divided into gossypol and nongossypol pigments. Levels of residual gossypol pigments, such as those found in the liquid cyclone flour (28), are considered to be the primary source of the greenish hue imparted in certain end uses (27, 5). These pigments can best be eliminated by using products made from gland-free and, therefore, gossypol-free varieties of cottonseed (29).

In the sunflower, oxidation products of chlorogenic acid and other polyphenol constituents, which can occur at levels as high as 3 to 3.5 g/100 g flour (18), will impart a discoloration in certain foods. Methods to remove over 90% of the chlorogenic acid from sunflower kernels by dilute acid or 70% ethanol leaching have been reported (30). Development of low chlorogenic acid cultivars is also underway (31).

Similarly, the potential for discoloration from rapeseed polyphenols has been suggested (32, 33). In all instances with all products, the significance and importance of this discoloration will depend upon the particular end use. For example, cottonseed flours can be effectively used in meat products, certain bakery items, e.g., cookies, chocolate cakes, doughnuts, and nonwhite bread dough systems without adversely affecting color.

Flavor characteristics of vegetable protein products will also vary with the type and the degree of processing. The flavor notes listed in Table I are those usually associated with the defatted flour exclusive of any bitterness or astringency due to unacceptable levels of residual hexane. These flavor characteristics are attributed to polyphenol constituents, to oxidized residual lipids and/or their derivatives. Therefore, storage conditions of the seed and processed flour, in addition to variety and environmental conditions of growth, can all contribute to the height of the flavor notes associated with the processed protein ingredient.

Conversion from a flour at 50% protein to a concentrate of 70% protein, to an isolate at 90% protein usually provides a progressive decrease in flavor. However, isolation procedures may also concentrate these flavor notes. In the selective extraction procedure for the preparation of cottonseed isolates (34), the undetectable cereal and green flavor notes of the flour are concentrated in the minor, nonstorage protein isolates.

The primary concern, however, must not be one of the flavor of the ingredient but rather the contribution of the ingredient to the flavor of the food product. This same cottonseed isolate, when autoclaved prior to use in a bread formulation, contributes an excellent cheese-like flavor to the bread (35). Similarly, Honkanen (12) reported that rapeseed protein concentrate with stronger flavor notes than a texturized soy flour control contributed less to the overall flavor of meat patties than the soy. Consumer evaluation showed a preference for the meat pattie with rapeseed concentrate over that of the all-meat control.

In turn, Sosulski and Fleming (18) showed that the flavor of weiners containing a sunflower concentrate, from which the phenolics were removed, was rated comparable in flavor to the all-meat control and significantly higher than products containing the defatted sunflower flour with phenolics or a soybean concentrate. The contribution to flavor just as with any other functional or qualifying characteristic of the protein ingredient is dependent upon use level and the chemical and physical environment to which it is subjected.

Of the vegetable proteins listed in Table I, only soybean, cottonseed and rapeseed have been reported to contain antinutritional factors. The trypsin inhibitor of soy is reduced to physiologically acceptable levels by moist heat during processing (36). Raw peanuts reportedly (37) also contain a trypsin inhibitor, but no physiological significance has been attributed to the roasted peanut.

Gossypol levels in edible cottonseed products are limited by FDA regualtions to a concentration of 0.04% of that which measures as "free" gossypol, with no limitation on bound or total gossypol (38). Functional cottonseed protein products with acceptable levels of gossypol can be obtained either by use of the liquid cyclone process (28) to remove intact pigment glands or by the growth of glandless seeded varieties (29). Unfortunately, for a number of technical and nontechnical reasons, commercial production of glandess varieties in significant quantity is still not a reality.

Numerous procedures for removing the glucosinolates of rapeseed have been devised (15). Sosulski et al. (11) have demonstrated that the levels in the low glucosinolate variety Tower (1.2 mg/g of defatted flour) can be reduced to acceptable levels (0.1 mg/g) for edible products by aqueous alkaline diffusion or water extraction of heat-treated seed. Here again, the economic viability of the processing approach must be weighed against the probable success and time required to achieve a solution via breeding. Reduction of glucosinolate levels to zero is still a high priority in both Canadian and European breeding programs (39).

Each of the vegetable proteins listed in Table I are limiting in at least one essential amino acid except rapeseed. A listing of the relative order of nutritive value of these proteins when evaluated by the PER (protein efficiency ratio) assay (40) would probably be rapeseed, cottonseed, soybean, peanut, and sunflower, with rapeseed values greater than those of the casein control, cottonseed equal or slightly below casein, soybean slightly lower than cottonseed, and peanut and sunflower essentially equivalent but significantly lower than soy.

Once again, however, in most instances the critical factor is not the inherent characteristics of the protein ingredient but rather the characteristics of the components with which the ingredient is combined. Milk and meat proteins have an excess of most of the essential amino acids. Therefore, combinations of animal and vegetable proteins should provide an increase in protein quantity and no significant decrease in protein quality.

Combination with the quality deficient cereals is another matter. Under these circumstances, soybean proteins will be the only vegetable proteins with sufficient excess lysine to increase significantly the PER of cereals. Sunflower proteins do, however, have a relatively high methionine content which could have a very useful complementation value.

Ideally, if protein quality is the primary objective, a multiple mixture based on amino acid complementation of the ingredients could be developed and related to the protein and amino acid requirements of the targeted group. Indeed, recent studies with humans at various age levels showed that vegetable proteins, specifically soybean and cottonseed protein, when fed at adequate nitrogen intake levels, performed better than might be predicted from rat studies (26, 41). These studies suggest that the nutritive value of vegetable proteins as a class have been significantly underrated.

The third and perhaps most dominant attribute of food systems to which protein ingredients contribute is texture. Dr. Wilcke has described in this conference various methods for developing texture in vegetable protein products (42). One might say that the texturized product has built-in functionality. This type of product is utilized as a discrete component to imitate, complement, or sustain the existing texture of a food system. Alternately, protein ingredients, i.e., flour concentrates and isolates, function in combination with the other components of a food system to develop or stabilize the desired texture of the system.

As Dr. Kinsella has pointed out earlier, texture-forming properties of proteins are due to the intrinsic physicochemical characteristics as dictated by composition and

TABLE II

Physical Characteristics of Vegetable Proteins

Protein source	Sedimentation coefficient	Molecular weight	Percent of total proteins	Physical-chemical phenomena
Cottonseed (35,44,45)	2S	15,-50,000	25	—
	7S	140,000	45	Dissociates in acid
	12S	180,200,000	20	Dissociates in acid, cryoprecipitates
Peanut (46,47,48)	2S	20,-50,000	5-8	—
	8S	142,-190,000	30	Associates in acid
	13S	330,000	55	Dissociates in acid, low ionic strength and cryoprecipitates
Rapeseed (48,49,50)	2S	13,000 50,-75,000	20-40	—
	12S	150,000 350,000	40	Dissociates in acid
Sunflower (52,53,54,55)	2S	20,-50,000	22	—
	11S	340,000	54	Dissociates in acid, alkali, and at high and low extremes of ionic strength, cryoprecipitates
	15S	600,000	12	—
Soybean (56,57,58)	2S	8,-2,100	22	—
	7S	180,-330,000	37	Associates at low ionic strength
	11S	350,000	31	Dissociates in acid, alkali and very low ionic strength, cryoprecipitates

TABLE III

Dispersibility Characteristics of Oilseed Proteins

Protein source	pH	Nitrogen water	Dispersibility - % sodium chloride
Cottonseed (34,59)	6.7	25	78 (3%)
Peanut (60)	6.6	84	63 (3%)
Rapeseed (49)	6.0	45	67 (10%)
Sunflower (18)	6.5	23	74 (5%)
Soybean (61)	6.5	88	83 (3%) 48 (0,5%)

environment (43).

The listing in Table II of some of the basic physicochemical characteristics of the proteins in the various oilseeds is in no way to be considered definitive. It contains many numbers that are approximations and many for which there are conflicting data. The data do illustrate the fact that there are many similarities and perhaps, more importantly, a number of differences among the proteins of the oilseeds.

All oilseeds except the peanut contain a group of low molecular weight proteins that represent 20% or more of the total proteins. Since the low molecular weight proteins tend to be high in lysine and the sulfur amino acids, the low proportion of these proteins may be a contributing factor to the amino acid deficiencies of the peanut. Rapeseed is also unique in that the low molecular weight protein fraction reportedly contains a large proportion of a single, very basic protein with an unusually hgih isoelectric point.

The major portion of the total proteins in each of the oilseeds is composed of one or more high molecular weight proteins. These proteins all exhibit very interesting association-dissociation phenomena that are related to molecular charge and are, therefore, environment dependent. The legumes are again different from the other oilseeds in that they each contain a 7S or 8S protein fraction that associates to a higher molecular weight under various conditions of acidity and ionic strength. These very unique phenomena of the major proteins of the oilseeds are the properties that determine functionality potential and versatility.

There are, of course, many distinct differences among these proteins in amino acid content and sequence, and consequently in hydration rates and solubility. These differences in turn affect extraction rate and dispersibility - another factor in the functional capacity of an ingredient. The differences in nitrogen extractability between the various defatted flours listed in Table III reflect not only inherent differences in hydration and solubility properties of the proteins, but also differences in the composition, charge, and solubility of the nonprotein constituents of the seed. Superimposed upon all of these is the impact of the highly organized, subcellular structure of the oilseed, which has been demonstrated to survive defatting and even some concentrate operational procedures (62).

It must also be recognized that many of the so called "functional characteristics" of defatted flours and concentrates, such as water absorption, fat absorption and consistency, are provided not by the proteins of the seed but rather by the complex carbohydrates, pectins, and hemicellulose components of the cells.

The Brabender Viscoamylograph patterns of an air-classified cottonseed protein concentrate containing relatively few cell wall fragments (Figure 1) and those of the air-classified coarse fraction rich in cell wall fragments (Figure 2) illustrate the relative contribution of these nonprotein components to the consistency of aqueous dispersions of these products (63). Similar effects have been demonstrated with sunflower and rapeseed products (64, 11).

The typical functionality test used to characterize vegetable protein ingredients, such as water absorption, fat absorption, gelation, emulsification, consistency, viscosity and various other rheological tests, are all attempts to define and/or predict the ability of the protein ingredient to contribute to the texture of the food system. Unfortunately, these tests tell us little more than the performance of the particular protein product under the specific set of test conditions utilized, which may or may not be similar to those found in any one particular end use. In addition, they provide essentially no information on how these protein ingredients will react with the components of the food system and how this reaction or lack of reaction will affect the desired texture.

In certain instances, functionality tests designed to relate

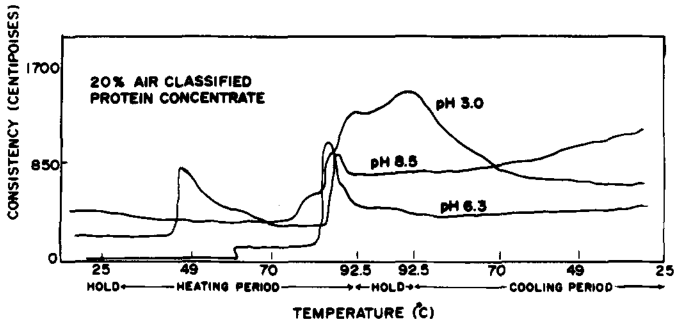

FIG. 1. Consistency profiles of 20% aqueous slurries of air-classified, glandless, cottonseed protein concentrate (70%) at different pH values.

to some aspect of end use texture are actually measuring the wrong characteristic. Oil emulsification, i.e., the quantitative measure of the amount of oil that can be emulisified by a protein ingredient, is a good example of this problem. Generally this test is considered to be a measure of the ability of the protein to emulsify and stabilize the fat of meat emulsions. Aside from the fact that meat emulsions usually contain animal fat rather than vegetable oil, it must be recognized that the important factor in the meat system is not the degree of emulsification *per se* (which is a direct result of the quantity of work put into the system), but rather the fact that the protein ingredient has the ability to heat set and stabilize the emulsified fat under the conditions of time, temperature and/or pH utilized. Thus, for meat emulsions, knowledge of the conditions under which a protein ingredient will gel is probably far more important than the amount of oil emulsified.

Whippability, or the ability of aqueous dispersions of a protein ingredient to produce foams, is another "functional" characteristic that is frequently reported. Here again foam volume and stability with time are the characteristics usually measured. Whereas, the important criteria, namely heat setability if the foam is to replace egg white, or the ability to form freeze-thaw stable whips similar to whipped cream, are seldomly evaluated. Inherent in the measurement of foam volume, however, is the economic advantage of increased product volume at constant ingredient input. Economic advantage, however, is not included in the definition of functionality given at the beginning of this paper.

Provision of a definitive evaluation of the functional properties of a food ingredient requires the coupling of an adequate knowledge of the composition, chemical, and physical properties of the ingredient under various environments, with an appropriate evaluation within the enduse system, including the impact of variables such as the order of ingredient addition. In such an evaluation, rheological measurements have a very important and specific purpose, namely, to define the optimum set of parameters that must be met.

Without the development of this dual information, routine functionality tests as provided by the ingedient producer and routine screening tests as applied by the ingredient user will continue to produce a valueless collection of data.

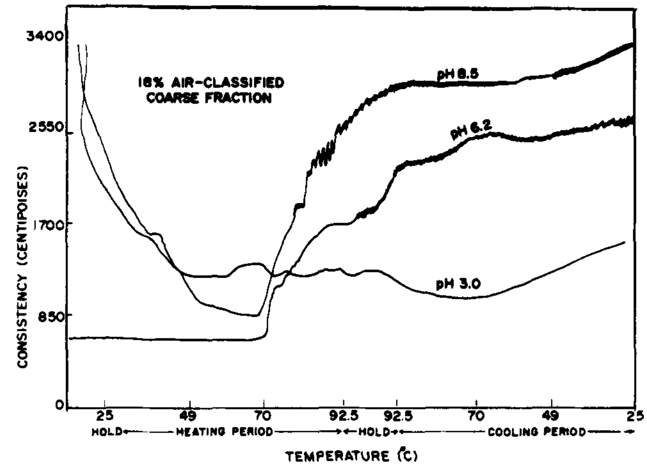

FIG. 2. Consistency profiles of 18% aqueous slurries of coarse fraction from an air-classifed glandless flour at different pH values.

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