tent (5).

Unfortunately, this protein has a pronounced taste and smell of cooked potatoes. Smell and taste are undesired, they are caused mainly by constituents of the potatoes adsorbed during the coagulation of the proteins. Furthermore, the taste is adversely affected by horny protein particles which are formed during protein precipitation. At consumption they are responsible for the impression of "sandiness." To avoid this impression, it is necessary to grind the protein particles to such a fineness that the taste sensitive papilla cannot notice the horny structure any more. Due to these properties, potato protein was used practically as a feed-stuff for chicken and pigs and partly as a milk powder replacement for growing cattle.

In our institute we tried to use potato protein coagulates without further treatment for human consumption. We enriched bakery products, especially crispbread, cookies, crackers, wafers and biscuits with potato protein (6). Negative effects on taste and smell were especially noticed in those bakery products where the dough had already passed a fermentation step. This can be explained by enzymatic reactions of the potato protein with accompanying components of the dried coagulates as well as by interactions with the flour and dough components.

The previously mentioned intensive "sandiness" can be noticed distinctly in bakery products with a high water content. It could not be removed completely, even though the particle size of potato protein was reduced to that of the flour particles. The hornification of the protein can be reduced to a certain extent by wetting the protein surface with a starch solution and a subsequent careful spray-drying. The addition of potato protein to flour mixtures will lead, in relation to its particle size, to a substantial increase in water-binding capacity of the doughs, resulting in bakery products with a higher water content. Unfortunately in this case the loaf volume is adversely affected (7,8).

Different bakery products tolerate various amounts of protein enrichment (9). Whereas in normal bread doughs the possibility of addition of potato protein is limited, the protein content in crispbread can be doubled without essential changes in its typical characteristics as crumb structure, specific volume, and hardness.

It can be deduced from this short summary of results that the use of unpurified potato protein for human consumption is limited due to many difficulties. To prepare pure potato protein, neutral in taste and smell, it is necessary to purify the raw protein carefully. The purification can be carried out preferably in two steps. In the first step, the decanted coagulate is suspended in warm water, whereby most of the accompanying components of low molecular weight, which are responsible for smell and taste, are removed from potato protein. The purity will increase to 90%. A following extraction step with alcohol will remove the rest of the undesired components (10); the protein content will amount to 93-95%.

The potato protein isolates obtained in this way have many fields of application. But it must be mentioned that in spite of careful purification there could be some risk factors involved, which up to now are not totally eliminated (11).

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Development of Field Pea and Faba Bean Proteins

F. BRAMSNAES and **H. SEJR OLSEN**, [1] Food Technology Laboratory, Technical University, DK-2800 Lyngby, Denmark

INTRODUCTION

This paper deals with legume seed proteins, namely proteins from field pea (*Pisum sativum*) and from field bean (*Vicia faba*), which most people today call faba bean. Both legumes belong to the N-fixing crops and are widely consumed as seeds by man. As for the production of protein concentrates or isolates, they are at the moment only used to a limited extent. However, because of their potential significance, they merit being included in this conference survey as future sources of vegetable food proteins. These two legumes present many advantages compared to the oil seeds with regard to the production of protein concentrates and isolates. The most pronounced advantages are that simple methods, like air classification and ultrafiltration, can be used as the separation steps.

COMPOSITION

Table I contains an example of proximate analysis of whole and dehulled pea and faba seeds (1). Methanol soluble sugars are ca. 7.4% for pea flour and 5.6% for faba bean flour (1).

Oligosaccharides, in particular stachyose and raffinose, are a little higher level in pea flour than in faba bean flour. In Figure 1, oligosaccharide contents are compared (2).

There is a considerable variation in protein content between cultivars. Bhatty (3) found 26 to 35% protein in 12 cultivars of faba beans. Continued breeding for high protein content is, therefore, still important. Another thing which seemingly is open for breeding is a desirable reduction of tannins.

Storage proteins in peas and faba beans are vicilin ($S_{20,w}$ = 7.1) and legumes ($S_{20,w}$ = 11.80). These proteins are similar to the 7S and 11S fractions of soy protein, but the legumin seems to possess a more compact structure than the 11S-fraction of soybeans. Furthermore, these proteins do not undergo association-dissociation reactions with change in ion strength to the same extent as is generally seen for soy proteins (4).

CROP YIELDS

Useful information about yields obtained in practical

[1]Present address: Novo Industri A/S, Novo Alle, DK-2800 Bagsværd, Denmark.

TABLE I

Proximate Analysis on Dry Weight Basis of Whole and Hand-dehulled Seeds of Field Peas and Faba Beans (1)

	Whole seed		Dehulled seed	
	Peas[a]	Beans[b]	Peas	Beans
1000-Seed weight (g)	123	342	---	---
% Protein (% N x 6.25)	25.7	27.9	29.1	34.1
% Starch	43.7	41.2	46.6	43.5
% Lipid; neutral[c]	0.9	1.0	0.9	1.2
% Lipid; polar[d]	1.5	1.0	1.3	1.3
% Ash	2.7	3.2	2.9	3.5
% Crude fiber	6.8	7.2	1.4	1.6
% Phytic acids	---	---	0.74	1.80
% Hull in seed	8.2	13.0	---	---

[a]Variety Trapper (Canada).
[b]Variety Diana (Canada).
[c]Hexane.
[d]Chloform/methanol.

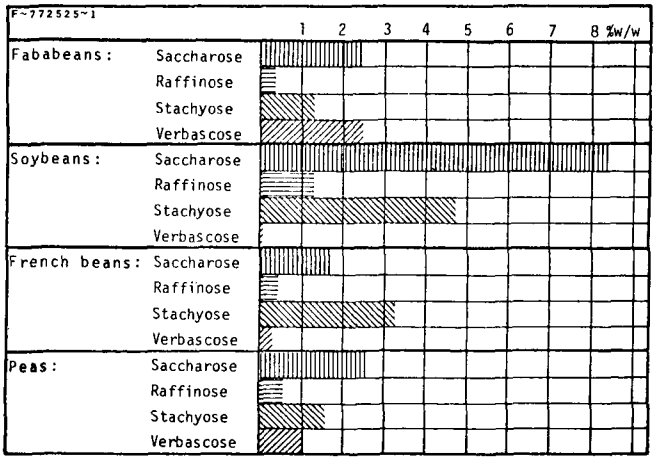

FIG. 1. Distribution of sugars in some legumes (2).

farming are always difficult to state. About 4,000 kg/ha has been mentioned as obtainable in Canada for faba beans and peas. In Norther Europe the yield is slightly less under practical conditions. However, on experimental lots in the Netherlands, 5,500 kg/ha of faba beans and in France 6,000 kg/ha of peas have been obtained. This corresponds to protein yields the same as for soybeans grown in USA.

In Canada and Northern Europe, one of the farmer's greatest problems with faba beans is a too late harvest in some years, and breeders are working on the early maturing varieties. Positive breeding results will be of the outmost interest to the farmers.

PRODUCTION OF CONCENTRATES AND ISOLATES

Concentrates

A wet process for peas called Slurry-Centrifugation has been developed at the Prairie Regional Laboratory, Canada. A schematic flow is given in Figure 2. Lime is added to raise the pH to around 9. The concentrate is pale yellow and bland in flavor (5).

This wet process involves either a major effluent problem or high drying costs. It was, therefore, a good step towards better economy when the Prairie Laboratory discovered that peas and faba beans are suitable for a combination of pin milling and air classification as illustrated in Figure 3 for faba beans (1). Whole or dehulled seeds are ground very fine, and the flour is classified in a spiral air stream separating starch particles (ca. 30 my) from protein particles (ca. 3-5 my). Dehulled seeds yield about 48% of a protein flour (8.5% N) from peas and about 48% of protein flour (9.9% N) from faba beans. As regards peas, the process has now been further refined and is commercially applied. The pea protein concentrate contains on dry basis ca. 60% protein, 3% fat and 2% crude fiber. The starch fraction containing 2% to 3% protein may be further purified. This starch is finding use in several industrial applications. Suggested uses for the protein concentrate are as meat extender and as protein enrichment of baked goods.

Isolates

When making isolates from faba beans, early researchers

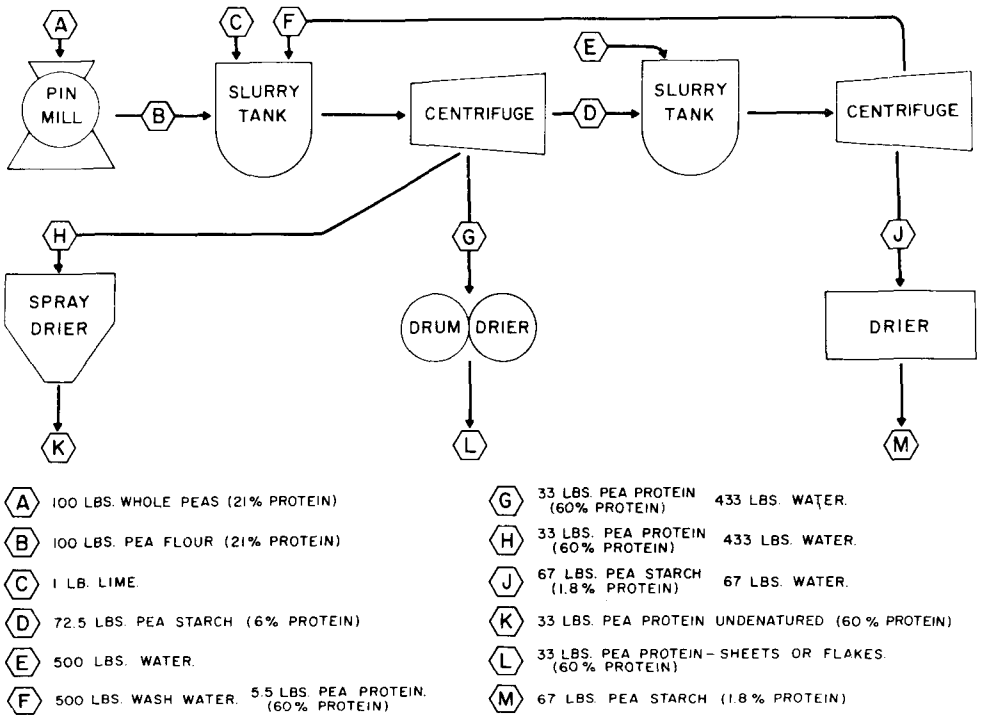

FIG. 2. Schematic flowsheet for wet processing of field peas (5).

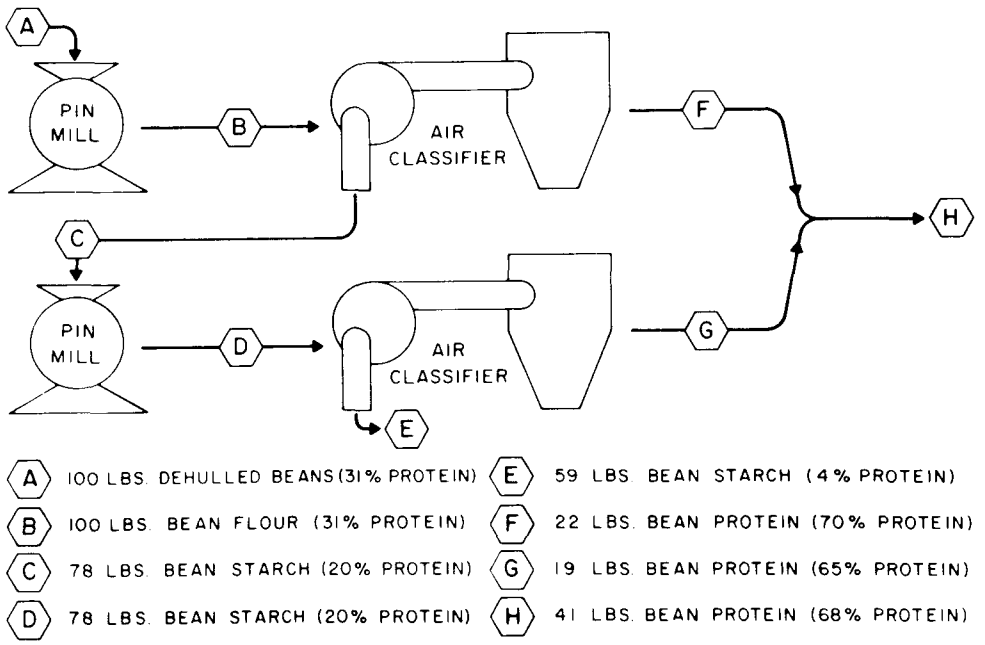

FIG. 3. Schematic flowsheet for air classification of faba beans (1).

extracted the protein under weak alkaline conditions followed by acid precipitation of the protein (6). In this process the whey, containing ca. 20% of the total protein, is discarded. Isolates extracted at alkaline pH have a dark color (7).

At the Food Technology Laboratory, Technical University, Denmark, work was also started using alkaline extracting conditions (8). However, it was discovered that tap water used in a continuous counter current extraction gave high yields of dissolved protein too (9). This is in line with later published extractability curves (7).

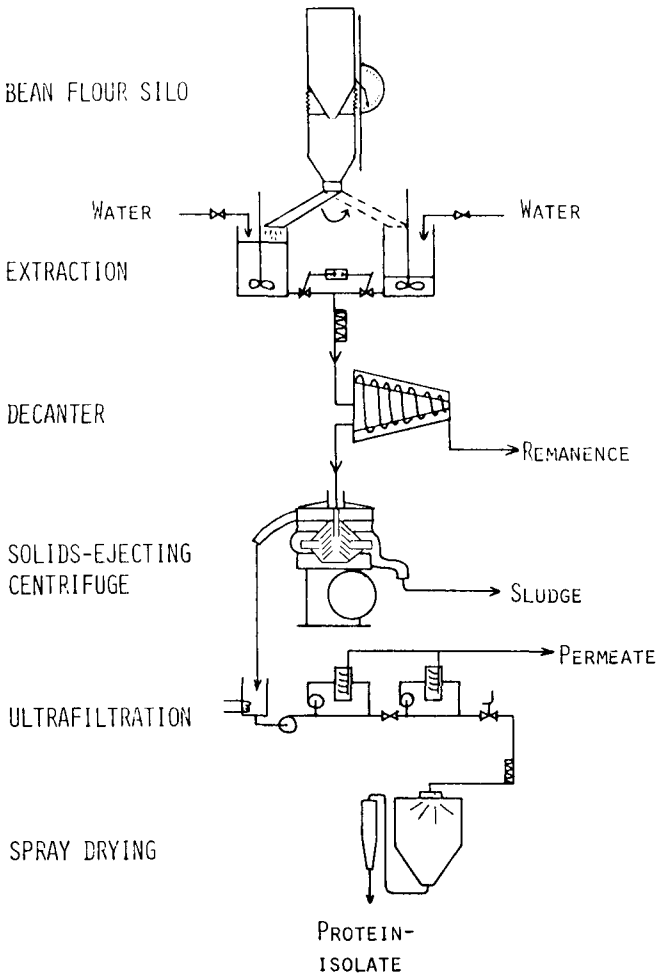

FIG. 4. Flowsheet of a pilot plant for faba bean isolate.

The final pilot plant which was built at our laboratory for continuous production is shown in Figure 4. Dehulled and dry milled faba beans are mixed thoroughly with cold water. The extraction takes place in two stirred vessels with a time delay of 30 min, so that one vessel is drawing off while the other is stirred. About 85% of the protein (N x 6.25) is extracted, and about 49% of the dry material from the faba bean flour is continuously separated with a solids content of 45% by a Decanter centrifuge. The extract is clarified in a solids-ejecting centrifuge before ultrafiltration or acid precipitation(10). Different process designs have been investigated for the ultrafiltration alternative (10) and (11), but the final pilot plant is based on a continuous two step ultrafiltration at 50 C. By this process a protein isolate with ca. 25% dry matter and 23% protein (N x 6.25) is obtained, and it is surprisingly found that it is possible to obtain a higher protein/dry matter ratio in ultrafiltrated protein isolate than in neutralized and precipitated protein isolate. This concentrate is spray-dried. Traditional acid coagulation has been performed in the plant as a batch process, and costs for the ultrafiltration process compared with traditional acid coagulation are found to be nearly identical (10).

A newly issued Canadian patent (12) describes a method for making protein isolates based on extracting the protein with a sodium chloride solution of 0.2 to 0.8 ionic strength and precipitating the isolate by dilution with water. It is claimed that a product with 95% protein can be obtained. No information is supplied with yields.

Nutritional Properties

The sulphur-containing amino acids are the limiting amino acids in faba beans and peas, but the proteins are excellent sources of lysine. The content of methionine + cystine is roughly 2.4 g/16 g N for both faba beans and peas. Using the FAO reference protein, the chemical score is 57%. Defatted soybeans have a content of methionine + cystine of 2.6-2.8 g/16 g N corresponding to a chemical score of 62-67%.

During production of refined protein products from faba

TABLE II

Trypsin Inhibitor Activity in Faba Bean Protein and in Soybean Proteins

	TUI/mg protein[a]
Raw faba beans (Kl. Thüringer)	14.5
Faba bean protein isolate (ultrafiltrated)	12.2
Faba bean protein isolate (acid precipitated)	6.5
Defatted soybeans	194.0
Soybean protein isolate (Promine D)	40.6

[a]TUI = Trypsin units inhibited (Method: Kakade et al. (15) slightly modified).

beans or peas, the content of methionine + cystine may be altered due to loss of certain protein fractions. Owing to the low content of the sulphur-containing amino acids, such technological processes should be favored which can improve or maintain rather than decrease the content. In order to obtain this, air classification or an ultrafiltration process may be preferred rather than acid precipitation because the whey fraction has a high content of sulphur-containing amino acids.

The mentioned proteins are very often mixed with other proteins, e.g., meat, milk or wheat, and the final food product should, therefore, be evaluated rather than the individual proteins. When faba bean proteins or soybean proteins are mixed with the above mentioned protein, the chemical score values are always enhanced and the same will be true with pea proteins. Flours, concentrates and isolates of pea and faba bean may, therefore, be used directly as protein enrichers in products like pastas, baked goods, etc.

Antinutritional Components

Ortanderl (13) has demonstrated the existence in faba beans of four trypsin inhibitors and two chymotrypsin inhibitors. In Table II we have compared the trypsin inhibitor activity of faba bean proteins and soybean proteins (14). Favism is often mentioned in connection with faba beans, and the interest has been concentrated on their content of vicin and convicin. It is possible to remove these glycosides in wet processes because in solution no absorption seems to exist between glycosides and proteins. Examination of air-classified protein indicates that the glycosides are closely related to the protein bodies in the raw bean (16). Hulls from the normal brown faba beans contain significant amounts of condensed tannins, which can cause growth depression in animals (17). Breeding for lighter colored hulls with less tannins has proved possible.

Functional Properties

In studying the functional properties of protein products from these legumes, it is necessary to realize that both the proteins and the accompanying carbohydrates of the products are responsible for the final behavior in a food product.

Vaisey et al. (18) have demonstrated that faba bean and pea concentrate prepared by air classification reduce the cooking losses to negligible values for broiled meat patties where 30% of the meat is substituted by legume protein concentrate and water. The air-classified products contain ca. 20-25% starch, which may be responsible for a significant part of the water-and-fat-binding properties of these products. By sensory evaluation of the legume-beef patties, Vaisey et al. (18) found that the flavor dominated the criticisms of the patties. The flavors were characterized as cereal-like, rancid and bitter. Drum drying decreased the undesirable flavors. Sensory evaluation of faba bean flours in a 5% flour slurry showed dried pea flavor and bitter after taste as the dominant flavor characteristics. Concentrates gave a somewhat stronger after taste. These products

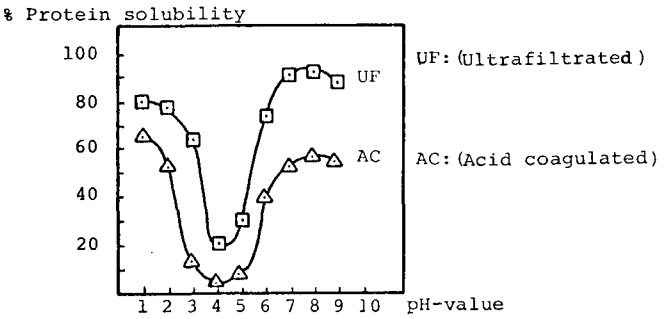

FIG. 5. Protein solubility curves of faba bean protein isolates.

contain 2 to 3% of unsaturated lipids, and heat treatment to inactivate lipoxygenase resulted in a decrease in dried pea flavor (19). Studies of the flavor should continue, but there is also a need for more refined, bland protein products, e.g., protein isolates or protein concentrates produced by acid wash. The mechanism of both the faba bean and pea flavor may be assumed to be similar to that of the soybean in some way. As demonstrated by Sejr Olsen et al. (20), the beany and "cooked soybean" off-flavors of defatted soybeans, white flakes. A similar process may be used to remove the flavors from the air-classified protein concentrates of faba bean or pea. Naturally, the product costs will increase due to a necessarily drying, but the value of the protein product will also increase due to higher eating quality of the final products. The mentioned off-flavors are not found to the same extent in the protein isolates produced either by the ultrafiltration or by the acid precipitation processes described previously.

Comparing the protein solubility curves for ultrafiltrated and acid-precipitated protein isolate, respectively, it appears from Figure 5 that denaturation of the proteins recovered by ultrafiltration is much lower than for proteins recovered by acid coagulation.

An important application of the protein isolates is a binder in meat emulsions for sausage production. For this application, gel-forming properties like those of actin and myosin in raw meat are desirable together with good emulsifying properties. The legume proteins vicilin and legumin are by use of crossed immunoelectrophoresis shown to be rather stable to heat treatment (21), and we have found that strong gels are formed by heat treatment above 100 C, where S-S-interchange seems to be involved. However, it would be desirable to have higher gel strength at lower temperatures.

As demonstrated by Hermansson (22), for acid-precipitated soy proteins, the gel formation is strongly reduced with increasing amounts of salt being added. We have not seen this with faba bean protein. Because salt is always applied in meat systems, this effect of salt should favor the choice of vicilin- and legumin-containing legumes like faba bean and pea.

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Development of Safflower Protein

A.A. BETSCHART, Western Regional Research Laboratory, SEA/ARS/USDA, Albany, CA USA

ABSTRACT

Development of safflower protein and safflower protein isolate (SPI) containing as high as 95% protein (N x 5.3) is described. SPI exhibits favorable nitrogen solubility, foaming, and bread-baking properties. Composition of SPI and select functional properties may be altered by the choice of pH used to precipitate the extracted protein (5 or 6). PER of SPI (1.26) was increased to as high as 2.13 by the addition of L-lysine at levels of 0.75% of the diet. Theoretical estimates of production costs for SPI are similar to estimates for soy protein isolate. SPI has been evaluated experimentally in pastas, baked products, and beverage systems. Nutritional and functional properties indicate that SPI has promising potential as either a protein fortificant and/or a functional ingredient in various foods.

INTRODUCTION

Safflower *(Carthamus tinctorius* L.) is one of the oldest cultivated oilseed crops. Originally grown for the dyestuff carthamin, safflower has been cultivated more recently for its polyunsaturated oil. Once the oil has been extracted, the remaining high protein meal is the raw material from which flours, protein concentrates, and isolates are derived. The potential role of safflower as a human food has been reviewed (1,2).

Production of safflower increased sharply in the 1960s, but has since stabilized. Although safflower is a relatively drought tolerant crop, yields improve with irrigation. Yields range from 250 to more than 3000 Kg/ha with an average of ca. 2000 Kg/ha (1). World production of safflower seed and resultant oil and protein indicates that more than 100,000 metric tons of protein are available from this source. Major producers include countries such as India and Mexico where indigenous protein sources represent a valuable resource both for their nutritional value and their impact upon balance of payments. If average values of 40% and 15% are used for oil and protein, respectively, Mexico had the potential to produce 120,000 and 45,000 metric tons of safflower oil and protein, respectively, in 1976-1977.

Although safflower oil is consumed by humans, the press cake or meal is commonly used as an ingredient in animal rations. In the U.S. two commercially produced meal fractions are available; a high fiber and a low fiber fraction containing 20 and 42% crude protein (N x 6.25), respectively. The seed generally consists of 50% each kernel and hull, or pericarp. Average compositional values are 40% crude fat, 15-19% crude protein and 20-25% crude fiber (1). Earlier workers have suggested various methods for developing flours and protein concentrates (3,4). Flours are bitter and extraction of both bitter and cathartic substances with 70-80% ethanol was recommended to prepare an edible concentrate (5). Both bitter flavor and cathartic activity have been associated with lignan glycosides; bitterness with 1-matairesinol-mono-β-D-glucose, and cathartic activity with 2-hydroxy-arctiin, a flavorless compound (6,7). The removal of these glycosides is imperative for the preparation of acceptable, edible protein products. The preparation of safflower protein isolates (SPI) represents one approach to this problem.

Safflower protein isolates combine the advantages of high concentrations of true protein (≥ 90%, N x 5.3), favorable functionality including solubility, foaming capacity and baking quality, and absence of all but trace quantities of lignan glycosides (1,8,9). In addition, through alteration of extraction and precipitation conditions, functionality of SPI may be partially modified (10).

SAFFLOWER PROTEIN ISOLATES

Nature of the Protein

Safflower protein, nearly 80% of which is located in the kernel, was subjected to classical fractionation on the basis of solubility (11). Major protein fractions were soluble in 1N NaCl or 0.1N NaOH, with these fractions containing 41.5 and 39.1%, respectively, of the nondialyzable nitrogen (12). Amino acid composition of the fractions varied significantly with the water soluble protein containing lysine in quantities equivalent to 84% of the FAO provisional amino acid pattern (13).

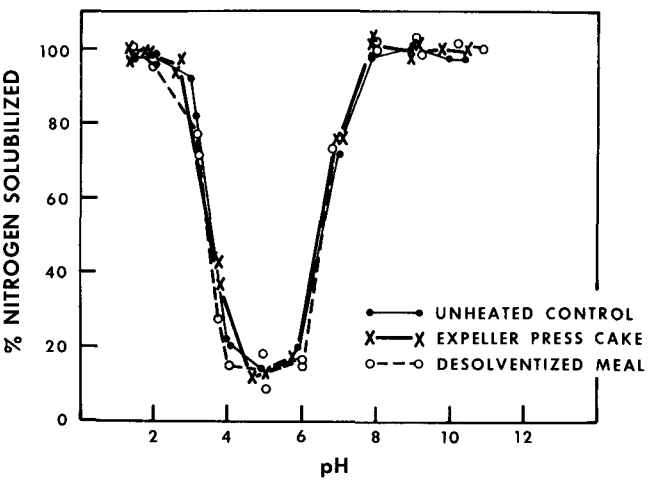

FIG. 1. Precipitation of extracted nitrogen from various safflower meals as a function of pH.