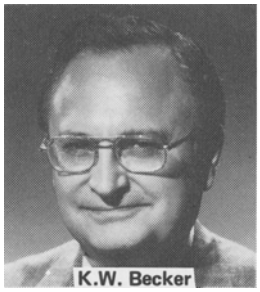
New Technology in Oilseed Proteins

KENNETH W. BECKER, Director of Cane Sugars, Oilseeds and Proteins, Woods; Food and Pharmaceutical Division, and **EUGENE A. TIERNAN,** Staff Consultant, Arthur G. McKee & Co., Chicago, Illinois, USA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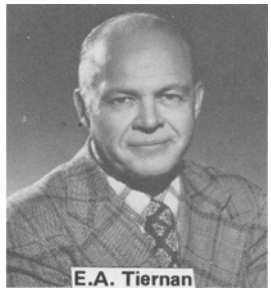
E.A. Tiernan

ABSTRACT

The protein industry is in a technical improvement revolution that will lead to tastier and flatulence free products. They will have longer shelf life, allow higher product yields, and be more efficient in energy conservation. The improved processes discussed include methods for making superior quality flours and grits, better extruded products, and higher quality concentrates and isolates. The new products will have high protein efficiency ratio ratings and a broad range of nitrogen solubility index. Some of the decision-making information that processors should have before appropriating capital are described.

INTRODUCTION

Today the world is faced with shortages of land, energy, water, and fertilizer. Milk, meat, and fish production–major protein sources–are down. With rising population, there is now only one acre of crop land per capita (excluding pasture, meadow, and grazing) on the average for all humanity. The all-important problem is to determine the best way to use it (1-3).

For these reasons, the day of oilseed proteins for human consumption appears near at hand. Of these, the soybean appears to dominate. It is important to note that an acre of land will grow enough beef to provide an adult with the required protein level for only 77 days, but an acre of soybeans will provide that same adult male the required protein level to sustain him for 2,224 days. Therein lies the clue to at least a partial, near-term solution to the world's food problem.

The use of oilseeds in edible foods is passing through a critical introduction period. In the U.S., the National Soybean Processor's Association reports the sale of soy proteins for human consumption shows a tenfold increase in the past 5 years. Yet, today, the total volume of soy, as well as other oilseed proteins, for edible use is still small. The mutual challenge to oilseed and food processors alike is simply stated, but complex of solution–to gain consumer acceptance of a much needed product.

What is needed are proteins without flavor or flatulence, having a long shelf life, a wide range of denaturation, and high water and oil absorption. These proteins should retain structural integrity through processing, cooking, and chewing. Better flavors and seasonings are likewise needed, which, after cooking and chewing, remain palatable. Finally, the proteins should be compatible for blending with local grains, vegetable proteins, and meats, approximating a protein efficiency ratio (PER) of 2.5, with sodium caseinate as a standard of comparison.

Other long-term alternatives to oilseeds proteins are single cell protein (SCP), leaf protein, and algae. It is not within the scope of this paper to discuss these in detail, but we feel a professional obligation to put them in perspective–for two reasons. First, the world some day just might need this technology for survival. Secondly, these proteins are potential large scale competitors, and the several technologies might ultimately merge for the good of mankind.

SINGLE CELL PROTEIN–AN ALTERNATIVE

Single cell proteins are easily transportable and can be made available in very large quantities. The microorganisms are extremely efficient protein producers–they double their number in a few hours. By comparison, half a ton of ox will produce about half a pound of protein per day, whereas half a ton of yeast will produce 2.5 tons of protein in the same period. However, most single cell proteins presently for human food applications have substantial drawbacks, such as high nucleic acid content, toxicity, off-flavor, and low digestibility, which must be solved technically. Some people estimate SCP may come into its own as a major source of human food in the next 10-15 years.

We must remember that the degree of control over the growing conditions for SCP is unique. Climatic fluctuations, the uncertainties of adequate rainfall, virus-pest-insect plagues, floods, droughts–none would affect SCP production. This process could even operate in the desert, requiring a comparatively small staff of trained personnel.

LEAF PROTEIN CONCENTRATE–SECOND ALTERNATIVE

Leaf protein concentrate (LPC) could also supply much of the world's protein needs. Laboratories in Hungary, Japan, England, the U.S., and other countries are working to perfect LPC processes, increase yields and palatability, and reduce flavor problems and cost.

From those studies, alfalfa appears to be the most attractive source for LPC. It will produce more protein per acre than most farm crops, up to 2,800-4,000 lb/acre in California as compared to 700 lb/acre from soybeans. Flow diagrams of two LPC processes are shown in Figures 1 and 2.

Figure 1 shows the production of green LPC curd. The screened juice is coagulated by direct steam injection. The curd is then drained, pressed, dried, and ground to a dark green granular product. Solubles are concentrated by

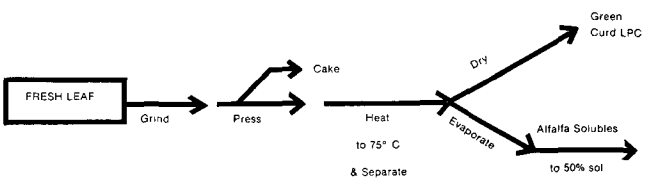

FIG. 1. Process "A" for preparing alfalfa leaf protein concentrate (Courtesy of Western Regional Research Laboratory, Berkeley, California.)

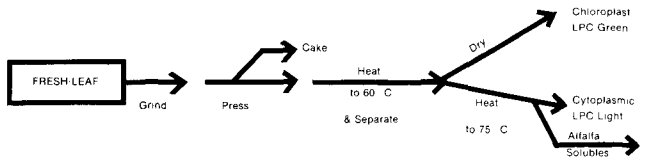

FIG. 2. Process "B" for preparing alfalfa leaf protein concentrate (Courtesy of Western Regional Research Laboratory, Berkeley, California).

TABLE I

Alfalfa LPC Advantages[a]

1. Amino acid equivalents to soybeans
2. 18% Protein residue–food animal feed
3. Dehydrating cost reduced
4. Crop
   - Saves fertilizer by fixing N_2
   - Renews itself 4-8 years
   - Grows in many climates

[a]LPC = leaf protein concentrate (Courtesy of Western Regional Research Laboratory, Berkeley, California.)

evaporation to 50% for use on feed.

Figure 2 shows a more complex process. The juice contains two protein forms. By choice of time, temperature, and pH, the chloroplast fraction can be agglomerated and separated centrifugally. The liquid containing cytoplasmic protein is polished, then heated by direct steam injection. The precipitate is flaky, but not curdlike. The light-colored protein is washed, then spray dried. Protein content may be as high as 90%.

Some advantages of the LPC process are given in Table I. Alfalfa is grown from Mexico to Alaska, yielding from 3 to 10 cuttings per year. In the U.S., an estimated 130 million tons of hay are produced annually, more than 50% of which is alfalfa–a prime source for LPC extraction. Its raw material cost for edible protein is about half that of soybean meal.

Several processes have been worked out to produce LPC, ranging from a green curd at 52% protein to a white powder at ca. 90% protein. One known commercial plant ran for nearly 4 years. There are production problems, as with any emerging technology, but the potentials for widespread use of LPC remain very high (4-9).

ALGAE–THIRD ALTERNATIVE

The algae have the highest intrinsic rates of photosynthesis and growth found among green plants. Human food and animal feed are already being produced from algae. The genus *Chlorella* has perhaps received the most research to this end. In Japan, full plant-scale production harvests algae from open ponds to yield green powder extract that can be used for animal or human consumption.

IMPROVEMENTS IN KNOWN TECHNOLOGY

In addition to recent patented technology, this paper contains descriptions of older technology that is now gaining commercial acceptance in oilseed flours and grits and textured vegetable proteins. Alcohol wash and dual-solvent systems, which improve flavor and shelf life, allowing vegetable protein use in meat and other systems, are described below. Oilseed technology is presented that will help reduce new plant capital investment and, in some cases, increase yields. These technologies now permit increased use of the less expensive flours, grits, flakes, meal, and concentrates as replacement in some markets for the more costly spun fibers and isolates.

EMERGING OILSEED TECHNOLOGIES

Although we only have time to hit the highlights of a few new protein processes, it is proper to give due recognition to the Northern Regional Research Laboratory (NRRL) in Peoria, Illinois, which has made so many major contributions to new emerging protein technologies. Some important current projects are:

1. Removal of flatulence factors in soy liquid products by use of enzymes, such as α-galactosidase, to hydrolyze raffinose and stachyose (10).
2. Use of ultrasonics to significantly improve soy protein yields, even from denatured, autoclaved flakes (11).
3. Alcohol and solvent wash systems to remove flavor compounds. Many NRRL scientists have worked on this. Three processes deserve special attention:
   a. 90-95% alcohols at ambient temperatures–removes some residual lipids and flavor factors.
   b. 90-95% alcohol wash, hot–removes most residual lipids, some raffinose and stachyose, beany biting throat catching flavors, complex mixtures of nitrogenous compounds, carbohydrates, phenolics, saponins, and oil from full-fat flakes (12-16).
   c. Hot hexane-alcohol azeotrope wash of defatted flakes–removes most residual lipids and intense flavors to give good flavored product approaching blandness with light color and wide NSI range (12,16-18).

Further details of the several alcohol wash systems will be disclosed below. It is important to emphasize that these processes appear to represent a major technological breakthrough.

In addition, we wish to recognize the important research that is being done by Southern Regional Laboratory (New Orleans) and Texas A&M University (College Station, Texas) to develop highly nutritious, edible proteins, having new and different functional properties, from cottonseed, peanuts, and coconuts. Two technologies being heavily researched are the aqueous extraction of oilseeds and the liquid cyclone process for cottonseeds (19-26).

DEVELOPMENT OF ALCOHOL AND SOLVENT WASH PROCESSES

As mentioned previously, one of the most significant developments in soy protein flavor improvement has been the alcohol and solvent wash processes developed at NRRL.

The hexane-alcohol azeotrope process and the hot or cold 90-95% alcohol processes could represent a potential for a major breakthrough in flavor improvement in the protein industry–especially soy proteins. These processes may permit the next generation of protein products to be introduced. The authors believe this new generation of products will permit use of 45-50% of concentrates in meat extenders, thereby creating a market for much more concentrate to be used than predicted a year ago.

Consider two factors: (a) residual lipids and (b) lipoxygenase, an enzyme in soybeans. Both are known to cause serious flavor problems. Residual lipids, probably bound in the protein structure, can be removed by hexane-alcohol azeotropes, also by hot 95% ethanol. Lipoxygenase, if not destroyed, will almost instantly (<60 sec) release many deleterious flavor precursors when full-fat soy flakes are processed in an aqueous medium (27-30).

Northern Regional Research Laboratory scientists emphasize that early removal of residual lipids is essential. Their studies indicate hexane-alcohol azeotropes do this best, with least flavor retention, good nitrogen solubility index (NSI), and lightest color. Hot 95% ethanol is also good, but the treated flakes have a lower NSI range, with color slightly darker, and may produce a grainy spray dried product. They have observed that some flavor reversion sometimes occurs after 60 days with defatted soy flakes extracted (washed) with hot 95% ethanol. They do not know the mechanism(s) which causes this, but state the flavor on some of these laboratory samples have burnt rubber and sulphide flavor (J.J. Rackis, personal communication).

NRRL further reports that defatted soy flakes first washed with hexane-alcohol, then "toasted," have the best flavor score of all. The soy flour rated 7.9-8.0 on a taste test of 1-10, with 10 being bland. The concentrate rated 8.3. Both products have a blandness rating equal to wheat flour (17).

The major milestones in the development of soy protein

TABLE II

A History of the Development of Alcohol and Solvent Extraction and Wash of Soy Proteins in the U.S.

1.	1940s	Alcohol washing improves soy protein flavor (36,37).
2.	1960	Defatted flakes washed with 95% (volume) ethanol or 91% (volume) isopropyl alcohol were debittered (38).
3.	1962	Alcohols denature proteins. Care should be exercised to protect functionality. During desolventizing, the flash method minimizes denaturation (39).
4.	1963	Seventeen solvent systems were studied on soy proteins, including (a) hexane-benzene-ethanol, (b) benzene-ethanol, (c) hexane-ethanol, (d) diethylether-ethanol, (e) alcohol facilitates lipid extraction by nonpolar solvents. "Aqueous alcohols. . .are better extraction solvents than ethyl alcohol mixed with hexane, benzene, or ethyl ether" (15).
5.	1960s	a. Almost all flavor is removed with residual lipids. b. Bound lipids are not removed by hexane. c. Hexane-ethanol azeotrope and hot 95% ethanol are effective in removing the more intense flavors of defatted flakes (12,18,40).
6.	1960s	a. Lipoxygenase is a cause of undesirable flavors. b. Lipoxygenase oxidizes linoleic and linolenic acids to hydroperoxides, which decompose to form a large number of undesirable compounds (27,28,41).
7.	1960s	Aqueous alcohols will extract phosphates, saponins, β-sitosteryl glucoside, genistein, triglycerides, and other unidentified compounds (13).
8.	1967	Cornell University researchers report lipoxygenase releases flavor precursors within seconds of contact of proteins with water (29).
9.	1969	Cornell researchers report ethyl vinyl ketone contributes green beany flavor (30).
10.	1970	a. Little or no saponin in hexane-ethanol azeotrope extracts. b. Soy saponins are not bitter (14). c. Pentane-hexane removed little if any beany bitter flavor. d. Aqueous ethanol removed most of the flavor. e. Hexane-alcohol azeotropes removed complex mixtures of lipids and most flavors.
11.	1971	a. Hexane-ethanol azeotropes remove oil and lipids. b. Ethyl-α-D galactopyranoside is a bitter tasting artifact formed from alcohol wash of soy flakes. c. Taste threshold for galactoside high enough so it will not contribute to protein bitterness (42).
12.	1971	a. Azeotropic mixtures of hexane-methanol, hexane-ethanol, or hexane-2-propanol on reextraction of flakes will improve flavor (43).
13.	1972	a. Mouthfeel of rewettable powders is improved (for beverage) by fine grinding, homogenizing, emulsifying, and spray drying (44).
14.	1974	a. Oxidative degradation of lipids is a common cause of objectionable flavors in foods (40). b. Bitter taste may involve oxidation of phospholipids (45). c. Soy phosphatidylcholine has been isolated from soy protein and is intensely bitter (46).
15.	1975	According to the Northern Regional Research Laboratory, for the best flavor results, the residual lipids should be removed from the defatted flakes by a hexane-ethanol wash. It gives the highest flavor and nitrogen solubility index (NSI) and best color. Hot 95% ethanol also removes most of the residual lipids, leaves slightly more flavor in the isolate, has a low NSI range, and a slightly darker color (J.J. Rackis, personal communication).
16.	1975	The hexane-ethanol washed flake can be further improved in flavor to the equivalent blandness of wheat flour by "toasting." Taste panel ratings are 7.9-8.0 for soy flour and 8.3 for concentrate, highest ever achieved by NRRL (17).

products with improved flavor qualities are detailed in Table II.

OILSEEDS CLEANING AND DEHULLING

To remain competitive in edible proteins, the oilseeds processor should use the best commercially available technology in seed selection, cleaning, and dehulling. Virtually all foreign material and hulls should be removed. In the authors' opinion, there is a superior methodology to dehull soybeans. The assumption is made that a soybean solvent extraction feed plat is adjacent to the food plant.

TABLE III

Hydrated Extrudates[a]

1. Use inexpensive oilseeds and animal proteins
2. Water solubles removed under compression:
   - odors, flavors, bitters
   - sugars, flatulence factors
3. Use of organic solvents instead of water
4. Protein
   - fibrous
   - spongy
   - highly soluble in water and oil
   - excellent sorption of flavors and seasonings
5. Engineered food
   - shredded fibers
   - meat-like structures and flavor

[a]British Patent No. 1,325,110.

Prior to storage, top quality beans receive major cuts of overs and unders—up to 10%. High volume cleaners are used, with rates to 9,000 bu/hr. From storage to processing, the bean stream is given a check cleaning. If stones or mud balls are present, cleaners with gravity tables are used. Rejects are 1-3%. Next, the seed is conditioned for dehulling using heat. Generally, the front end, hot dehulling method is the best system to remove seed coat. Close control of heat, time, and humidity is essential. Too little heat is ineffective in hull release. Too much heat and/or moisture allows crimping of seed coat into seed meat by the cracking rolls. Upon cracking into about sixths, the seed separates, leaving small "parachute" hulls and a minimum of meat fines. Aspiration is then applied (31).

Hulls run 7-8% of the bean, so a 10-12% cut by moderately heavy aspiration will get virtually all the hulls and some meats. This cut is sent to the feed plant preparation building. "The main stream (-4.5 + 18 mesh) is ready for conditioning prior to flaking and will be of good quality if all operations are properly executed" (31).

"If no feed plant is available, the liftings (ca. 12%) are routed to the reclaim system. This is small compared to primary dehulling. We recommend a +6 mesh cut be sent directly to the hull stream. There are no meats in it. The reclaim stream is now -6 + 18 mesh. For best results, separate it by small aspirators since the largest hulls in it will have a lower terminal velocity than any of the bean meats. Correct sizing of aspirators, fans, and sifters is important. So is control of time, temperature, and humidity prior to cracking. Power requirement is modest, maintenance low" (31).

TEXTURIZED VEGETABLE PROTEINS

Until recently, extruded products were used primarily in blends, as extenders, or alone where they could be heavily seasoned. Their use was limited to 30% or less as extenders. Two prime limiting factors were:

- Continued presence of off-flavors
- Lack of the fibrous, meat-like structure of spun fibers

Today this is changing. New technologies have emerged for extrudates. Flavor is much improved. Extrudates have more of a meat-like quality. Most new processes are proprietary and secret. Two which can be discussed are:

- The Wenger Uni-Tex double extrusion process
- A process described by British Patent Specification 1,325,110

The first has been discussed by previous speakers. These discussions will be confined to the improved technology shown by British Patent Specification 1,325,110 (32).

The British process produces pieces of extrudate using less expensive flour, grits, or flakes as opposed to costly isolates and concentrates. From this material, it produces a low cost meat substitute having many, if not all, the advantages of spun filaments. A synopsis of the Patent Specifications is shown in Table III.

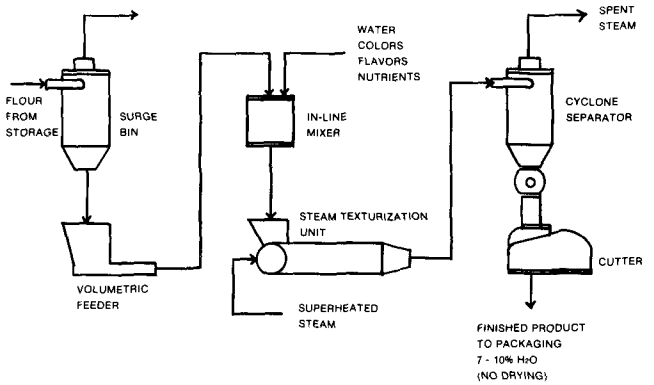

FIG. 3. Steam texturization process (Courtesy of General Mills, Inc., Minneapolis, Minnesota).

TABLE IV

Product Characteristics of Steam Texturization[a]

1. Flavor
   - bland
   - more can be used in blends
2. Absorption
   - water – 300% by wt
   - fat – good
3. Structure
   - similar to textured soy
   - excellent after dehydration
4. Bacteria count
   - low

[a]Courtesy of General Mills, Inc., Minneapolis, Minnesota.

This means the oilseed industry processor can start with economical materials. From these, at lower cost than spun filament or extruded isolate, a meat analog can be produced. It could mean less use of isolates and far greater use of flours, grits, and concentrates.

STEAM TEXTURIZATION

Among the general class of expanded, textured soy protein products, those produced by General Mills' Steam Texturization Process represent new technology. Such systems are currently in operation in the U.S., Canada, and Japan, with one in the United Kingdom to go on-stream in May, 1976. The process (Fig. 3) is patented (J.L. Holihan, General Mills, personal communication; 33). The important product characteristics of the Steam Texturization Process are illustrated in Table IV.

NEW RAPESEED TECHNOLOGY

Rapeseed is one of the five most widely produced oilseeds in the world, gaining worldwide popularity in the '60s. The principal countries growing it are India, Canada, Pakistan, France, Poland, Sweden, and East and West Germany.

Dr. Ragnar Ohlson and his associates, and the Swedish companies AB Karlshamns Oljefabriker and Alfa-Laval AB, have together developed a new process for the production of a nontoxic, bland, light colored protein concentrate. It is our privilege, for those of you who did not hear or read his work, to give a brief synopsis of his paper (34).

In the past, the main objection to the use of rapeseed meal for animals has been its content of deleterious glucosinolates. "By means of endogenic enzymes, myrosinases, the glucosinolates are split into the deleterious substances: isothiocyanates or oxazolidinethiones; and glucose and bisulphate." Other objectionable substances present are tannins, sinapine, and phytic acid. These have negative nutritional effects. The gross composition of rapeseed (34,35) is 45% fat, 25% protein, 18% carbohydrates, 8% crude fiber, and 4% ash. Rapeseed on the world market comes from different species generally belonging to the genus *Brassica*.

TABLE V

Typical Analysis of Rapeseed Protein Concentrate (from *Brassica napus*, Winter Type)[a]

Component	Content in dry matter (%)
Protein (N x 6.25)	65
Protein (N x 5.5)	57
Fat	1
Carbohydrates (excluding fibers)	28
Crude fibers	7
Total ash	7
Glucosinolates	0.06

[a]Courtesy of Dr. Ragnar Ohlson, AB Karlshamns Oljefabriker, Sweden.

Five different myrosinases have been found. Heat treatment deactivates them. The process for production of rapeseed protein concentrate (RPC) consists of four basic steps: (a) dehull, (b) deactivate myrosinase by heat treatment, (c) leach out glucosinolates with water, and (d) extract the oil.

Briefly, the cleaned seeds are crushed in roller mills. By screens and gravity tables, a meat fraction is obtained. This is treated with hot water to deactivate the glucosinolate-splitting enzymes and to lower the protein solubility. The process is countercurrent continuous leaching with water after this point. The detoxified seed meat is dried in a fluid bed drier. The oil is obtained by solvent extraction, or prepressing and then solvent extraction. The RPC is then desolventized, preferably in a "flash" or vapor desolventizer, and has the characteristics shown in Table V. The RPC oil residual is 0.5-1.5% (34,35).

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