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MARKETING POTENTIAL FOR OILSEED PROTEIN MATERIALS IN INDUSTRIAL USES
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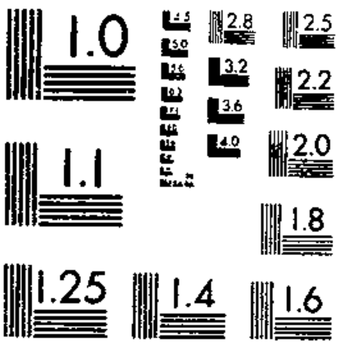
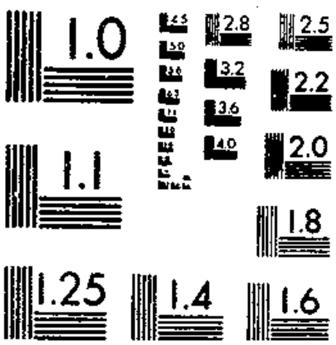


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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NATIONAL BUREAU OF STANDARDS-1963-A

Technical Bulletin No. 1043, 1951

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Marketing Potential for Oilseed Protein Materials in Industrial Uses

A report of Arthur D. Little, Inc., under contract as authorized by the Research and Marketing Act

INTRODUCTION

Four principal oilseed crops make large contributions to farmers' incomes. They are cottonseed, soybeans, peanuts, and flax. In 1949 they contributed considerably more than a billion dollars to farm income and they utilized more than 12 percent of the total cropland acreage. The largest source of income from these crops was the extracted oil, but the meal of high protein content, a residual from the oil extraction process, is an increasingly valuable source of protein materials for feed, food, and industrial uses.

The dry protein content of oilseed meals reached almost 7 billion pounds during 1949. About 98 percent of this protein was utilized for feed and fertilizer. The remaining 2 percent was almost evenly divided between industrial uses: the protein was used primarily for its physical or chemical properties or for food uses in which its human-nutritional properties had value. The quantity absorbed by industrial uses are relatively small compared with the total supply, but the 58 million pounds utilized in that year provided a higher return per unit to the supplier than did the portion that was used for feed. Continuing research by industrial and governmental laboratories indicates that future industrial utilization of oilseed proteins perhaps could reach five times the 1949 figure within the next few years.

The data on which this analysis is based were collected during the period September 1949 through July 1950. Since that time, changes have taken place in the oilseed situation and in economic conditions in general. Several notations have been made throughout the text to bring the information contained therein up to date as much as possible. Although this study was originally intended to aid developmental research in expanding the outlets for oilseed materials, the report now is of value in helping to disclose the role of oilseed

[1] Submitted for publication May 18, 1951.

materials during the present emergency. Oilseed materials are and can be used to supplement and replace materials in critical uses that are in short supply at the time this manuscript is going to press.

Protein from the major supplying crops is derived from widely scattered agricultural areas. With cottonseed coming from the South and the Southwest, soybeans from the Middle West and the South, peanuts from the South and the Southwest, and flax from the northern Great Plains, the utilization of these crops is important to almost every agricultural area. The interchangeability of these crops and the byproduct nature of the protein meal means a complex pattern of supply relationships. The substitution of soybeans for crops that are under acreage control, as corn and cotton, and the interrelation between peanuts for edible and for oil uses make the supply pattern even more complex.

Increased production of fats and oils since World War II, to offset the critical supply situation, resulted in a like increase in the residual protein meals. So far, the increased production of livestock has consumed this increased supply. But the need for research to assist in the advantageous utilization of these valuable protein materials is evident.

The nature of this study necessarily demands a relatively long and technical report. The data are presented in major groups of uses or application: Textiles, paper coating, wood-working glues, other adhesives, water paints, rubber, plastics, asphalt products, and miscellaneous uses. An additional section contains the data on supplies of the several oilseed protein materials. Many of the applications are not limited specifically to one of these listed categories. In such instances, cross references are made, when possible, to prevent duplication in presentation.

As a part of the work undertaken by the contractor, specific recommendations on research needs were collected from many of the organizations interviewed. Although general statements are given in this bulletin, derived from the data obtained in regard to specific research needed, most of these suggestions have already been supplied to interested parties.

OBJECTIVES OF STUDY

This study was designed to ascertain the present status of oilseed protein meals in industrial uses and to measure the potential which might reasonably be expected in these uses within the next few years.

The quantity of oilseed protein consumed in industrial uses has been increasing gradually for several years. The proportionate use of protein materials in specific uses has been decreasing but in several instances the growth of these industries has increased their total utilization of protein. The decline in industrial use of protein has been attributable chiefly to the use of starches and synthetics in the adhesives fields. The general feeling among those who were interviewed in the course of this study indicates that the large store of basic fundamental information that is available regarding the competing starches and synthetics has placed these commodities in a better competitive position in relation to protein materials. Research on the basic characteristics of starches and in the application of synthetics to specific uses has far outdistanced the available knowledge on the physical and chemical characteristics of the protein molecules.

Those in the U. S. Department of Agriculture who are concerned with physical research on oilseed proteins had suspected that the protein materials were in a poor competitive position because of lack of research. They wanted to learn the possibilities as to the future industrial use of these materials in order so to direct their research that it might more easily contribute to expanding the industrial uses.

To fulfill the major objective of the study it was necessary to learn the characteristics that are wanted by the major users in both the proteins now used and in the competing materials in these uses. The data presented in this bulletin supply to governmental and industrial research organizations information which may guide them in some of their future researches.

METHOD AND PROCEDURE OF STUDY

The basic method used in this study was a field survey to obtain opinions of representatives of selected industrial organizations that supply or use oilseed protein materials or competing products. A total of 222 interviews with representatives of 195 companies were completed. The contract with Arthur D. Little, Inc. required at least 100 interviews, including 30 specified suppliers. Most of the information was obtained in personal interviews with the appropriate representatives of each organization. The remainder of the interviews were made by telephone, usually after letters had been sent. Less than a dozen interviews were based on a mere exchange of correspondence. The personal interviews were mainly in large industrial areas and, because of the nature of the using industries, were scattered from Maine to Washington and from California to Georgia. Interviewing on this study took place during the period of September 1949 to July 1950.

The selection of firms to be interviewed was determined in the following way. The Bureau of Agricultural Economics furnished the contractor with the names of key suppliers and users of vegetable protein materials. These firms represented the nucleus of the sample. To expand the sample, these firms were asked to suggest possible firms to be interviewed. Other firms were included on the basis of the contractor's acquaintance with them or their convenience to other companies to be interviewed.[2] Basically, the criteria used for the final selection of firms to be interviewed were (1) the size of the firm in the industry, (2) the kind and extent of the research program being carried on there, and (3) the special interests of the firm.

Users were interviewed in almost all of the industries in which protein materials are used. This meant a scattering of interviews over far too many industries to leave enough in any one industry to warrant scientific sampling within it. For the protein-using industries most important to this survey, however, organizations that repre-

[2] Relatively few raw-material suppliers were interviewed beyond the 30 specified in the contract. This was because (1) the protein-supply situation was found not to be a major factor in the choice of material used except in the case of peanut proteins, wheat gluten, and casein, and (2) intermediate suppliers and users tended to be better sources of information on protein-use characteristics.

sented large proportions of the total production were interviewed, and indirect appraisals of the entire industry were obtained through suppliers.

Nearly all organizations with whom interviews were sought responded cooperatively, but the nature and extent of their responses varied greatly. Such variables were involved as their interests and information, the policy of the industry and organization, willingness to assist Federal research, and the time at the disposal of the interviewed men. It was difficult—in the instance of some industries impossible—to obtain reliable quantitative estimates for the industry; sometimes it was difficult to get even reasonably good bases from which these might be estimated, such as the use of estimates made by individual companies of their own operations.

Interview outlines were prepared in advance, and were modified after initial trial. Although they were freely adapted to the major separate industries, to obtain from each organization information on those points on which they could contribute most, usually required considerable improvisation during the interview. After each interview a memorandum was prepared covering practically every point for later use in preparing the report of the contractor.

Personnel engaged in the interviewing were a highly trained group. Besides having considerable experience as interviewers, they were chemists or engineers specially trained in the fields of technical research in which they were interviewing.

In addition to the information obtained from interviews, data were assembled from standard reference sources relating to supplies, prices, protein content, physical constants, etc. There were no substantial attempts to make any general reviews of the literature of the subjects because of the emphasis of this assignment on a direct field survey.

SUMMARY REGARDING USES IN INDUSTRY

Oilseed meals predominate among the sources of protein. Only a small quantity is used industrially. Nearly all of the nonfood industrial uses for oilseed proteins with the exception of the uses of zein have been achieved at the expense of casein, yet their total use is still essentially no more than that of casein. Further inroads on casein markets are expected by research men as improvement of oilseed protein isolates continues, except to the extent that the costs of casein become more favorable to such uses than those of oilseed proteins. This is a possibility for the intermediate future but is generally considered improbable for the long-term future. But for only two among the large markets for animal glue and gelatin (warp sizing and photographic emulsions) do oilseed proteins appear to be seriously considered, and synthetics are of principal development interest for both.

The following tabulation indicates the preponderance of oilseed meals among protein sources, and the small quantity used industrially. It also summarizes the supply situation of oilseed proteins and competitive animal protein byproducts used in industry. This is based for raw materials on the year beginning October 1948. Estimates of use are of the current annual level. All data are in millions of pounds of contained dry protein.

The principal natural proteins production, U. S., 1949

Item	Dry protein	Item	Dry protein
Basic materials:	*(million pounds)*	Estimated uses, etc.—Continued	
Oilseed meals:		Oilseed meals, etc.—Con.	*(million pounds)*
Soybean	3,895	Other industrial uses—Con.	
Cottonseed	2,126	Zein	5
Corn gluten	424	All other	5.5
Peanut	85		
Flaxseed	468	Total	58.0
Total	6,998	Casein	54
		Glue	130
Fish meal	117	Gelatin:	
Tankage, etc	465	Food	37
Estimated uses except wool, feed and fertilizer:		Other	13
Oilseed meals and products:		Total	50
Food uses	64		
Other industrial uses:		Egg	2
Soybean isolates	27	Blood albumen	1
Soybean meal	20.5	Blood soluble	4

Soy-protein isolate and soy meal are by far the leading oilseed proteins used in industry.[3] Soy flour, zein, and corn gluten, are also used in industry as are small quantities of cottonseed meal and, irregularly, peanut meal. Table 1 gives a summary of their estimated uses (annual rates as of early 1950), together with the uses of casein, their chief competitor. Estimates of their trend and outlook are included. The table also carries estimates (sometimes very rough guesses) that have been made of the quantities of oilseed proteins which might ultimately be used if these, and processes for their application, are developed as well as may be reasonably hoped; and estimates of the probability of reasonable success in such a development. In estimating reasonable success in development, no implication is intended that any particular portion of the estimated potential will be achieved.

Textiles

Although only a few million pounds of regenerated protein fibers, made from zein and from casein, are currently produced in this country, one of the most promising possibilities of increased industrial use of oilseed proteins lies in this field. The production of fibers from peanut protein in Britain and the development of keratin fiber in this country tend to substantiate this point of view. The potentialities of the development of regenerated protein fibers generally provide the best justification for the fundamental research on proteins that can contribute to proper development.

Regenerated Protein Fibers.—Fibers and monofilaments made of regenerated or modified oilseed proteins together represent one of the four principal opportunities for oilseed proteins in the textile indus-

[3] The contract specifically excluded food, feed, and fertilizer uses of protein materials from this study. This was done to provide as intensive a survey of industrial uses of protein materials as possible with the funds available.

TABLE 1.—*Estimates of present and potential markets for casein and vegetable proteins*

Item	Casein	Vegetable proteins					Total casein and proteins	Trend and overlook	Potential after development	Probability of reasonable success in development
		Soy-protein isolate	Soy flour	Soy meal	Zein	Corn gluten				
Textiles:	*Mil. lb.*	*Mil. lb.*	*Mil. lb.*	*Mil. lb.*	*Mil. lb.*	*Mil. lb.*	*Mil. lb.*		*Mil. lb.*	
Fibers	0.5	0	0	0	2.5	0	3.0	Good	30–100	Good.
Warp size	[1]	0	0	0	0	0	[1]	Poor	12	Fair.
Permanent size	1.3	0	0	0	0	0	1.3	do	[1]	Poor.
Paper coating:										
Pigment coating	20.0	14.5	[1]	0	0	0	34.5	Mixed	35–75	Fair to good.
Wallpaper coating	[2]	5.0	2.5	[2]	0	0	7.5	Poor	5	Fair to poor.
Insulating board	[2]	[1]	0	0	0	0	[1]	Fair	2	Fair.
Paper size	[2]	[1]	0	0	0	0	[1]	(?)	(?)	(?).
Woodworking:										
Softwood plywood	2	0	1	35	0	0	38	Fair to poor.	Same	Good.
Hardwoods	1	0	0	7	0	0	8	do	Sl. increase	Do.
Other adhesive uses:										
Solid fiberboard	0	1	0	0	0	0	1	Good	4	Good.
Corrugated board	0	0	0	0	0	0	0	Fair	1–30	Fair to poor.
Other fiber containers	0.5	0.1	0	0	0	0	0.6	do	2	Fair.
Multiwall bags	1	[2]	0	0	0	0	1	Poor	1–6	Do.
Prepared adhesives	1	[2]	0	0	[2]	0	1.2	do	4	Do.
Cork	[2]	[2]	0	0	[1]	0	0.6	Good	4	Good.
Water paints	6	2	[1]	0	0	2	10	Fair to good.	10	Do.
Spirit varnish coatings	0	0	0	0	2	0	2	do	3	Do

Rubber products:										
Tire cord dips	4	0	0	0	0	0	4	Poor	5	Fair.
Latex adhesives	2	0	0	0	0	0	2	Fair to good.	2	Do.
Rubber dispersions	0.1	0	0	0	0	0	0.1	Fair	Same	
Plastics:										
Extruded	3	0	0	0	0	0	3	Fair to poor.	1–5	Fair to poor.
Fillers	0	0	(2)	0	0	0	0			
Asphalt products:										
Felt base floor covering	2	1	(1)	(2)	0	0	3.3	Fair	3	Good.
Emulsions	(1)	0	0	[3] 0.5	0	0	1	do	1	Fair.
Food:										
Nutritional, etc			(60)				(60)			
Seasonings						[4] (35)	(35)	Mixed		Large Fair.
Whipping, gelling agents	0	[5] 2	0		0	0	2	Fair	10	Do.
Dyastatic enzyme	0	0	0	(?)	0	0	(?)	(?)	(?)	(?).
Industrial nutrients						(6) (?)				
Miscellaneous uses:										
Insecticide emulsifiers	(1)	0	(2)	0	0	0	(1)	Poor		
Fire foam liquids	0	0.25	(2)	0	0	0	(1)	Fair to poor.		
Printing inks	0	(2)	0	0	(1)	0	(1)	Good	5	Fair to good.
Cosmetics	(2)	0	0	0	0	0	(2)			
Leather finishing	0.6	(2)	0	0	0	0	(1)	Fair	0.5	Fair.
Photography	0	0	0	0	0	0	0	Good	7	Fair to poor.
Not elsewhere classified	8	(1)	(1)	4		(1)	13			
Total	54	[5] 27	5	46.5	5	2.5	140			
Protein content	54	27	2.5	21	5	2.5	112			

[1] 100,000 to 500,000 pounds.
[2] Under 100,000 pounds.
[3] Mostly cottonseed meal.
[4] Mostly wheat gluten.
[5] Including 2,000,000 pounds neutral aqueous extracts; not standard alkaline acid-precipitated extracts.
[6] Steep-liquor products.

try.[4] The size of the potential market, which can be measured from millions of pounds to several hundred million pounds per year, depends not only on the ability of the fibers to compete in price with existing and prospective synthetic fibers, but also on improved knowledge by the textile industry on how to utilize these new fibers to the fullest advantage. The production in the United States in 1949–50 of fibers and monofilaments from oilseed proteins and from casein was less than 3 million pounds.[5] More research of a relatively basic character will be required if they are to compete more effectively with the newer synthetic fibers now being commercialized.

It is possible that regenerated protein fibers may supplement or replace in part some natural fibers now in use. Even part of the manufacturing area held by nylon and some other synthetics is a current objective of at least one large company in this field. It is basing its expectations on the exceptional resilience which these fibers seem to possess but which most synthetics lack. This entire fiber field has substantial strategic as well as economic and technical significance.

It is much too early to estimate the potential market for regenerated protein fibers or the newer synthetic fibers in staple form, either in replacing natural protein fibers or in noncompetitive uses. Our growth of population is expanding the total market for fibers. Moreover, the lower cost and the "tailor-made" possibilities of these regenerated fibers suggest their potential use for many purposes for which natural protein fibers are now too expensive or are not well suited, just as rayon and nylon have developed many markets not previously held by silk, and as protein monofilaments now may be reaching both into and beyond the markets held by horsehair.

Two types of regenerated protein fibers, Vicara (a staple fiber from zein) and Caslen (a monofilament from casein) are in production in the United States; another from keratin is approaching production here; and fibers based on peanut protein are under development by the largest British rayon company, and are about to be commercially produced by the largest British chemical company.[6] Hence, although world production in 1950 will probably not exceed a rate of about 5 million pounds (using an equivalent quantity of pure protein) if all goes well, the 1955 production could become 10 times as large, with further growth beyond that.

Regenerated protein fibers appear to have characteristics—notably the combination of warmth and resilience—which, when more fully developed, will permit them to compete in substantial parts of the market against any synthetics now known to be in production or under active development. Their disadvantages—notably poor wet strength—have been subject to steady attrition through continuing research, and appear capable of substantial further improvement, especially as the current knowledge of protein molecular structures, which is now limited, is broadened. It cannot now be predicted to what extent oilseed proteins may continue their present dominance

[4] One of the four opportunities is through tire-cord dips. This is discussed in the section on rubber beginning on page 77.

[5] The production rate in May 1951 is believed to be about 5 million pounds of synthetic fibers from oilseed proteins and casein.

[6] Imperial Chemical Industries, Ltd., has begun commercial production of this fiber at an annual rate reported to be 10,000,000 pounds.

in this field. Other proteins that are now cheap—from fish-processing plants, meat and poultry packers, and wool processors and shoddy mills—are available. Some of these are definitely attractive to research workers.

Warp Sizing.—Warp sizing offers another principal opportunity for oilseed proteins. It consists of sizing-filament rayon warp threads before they are woven; the sizing is removed later. The potential market is now about 12 million pounds per year. Its achievement by oilseed proteins would probably require more basic development than has yet been provided. Inroads by synthetics would probably be reversed if prices for proteins should drop substantially. Modernization of warp-sized mills may aid the position of oilseed proteins in this industry.

Textile Finishing.—Textile finishing offers another opportunity in the field of permanently sizing woven goods. This area is divided into hundreds of specialized applications. Oilseed proteins may eventually be adapted for use in some of these, probably in small specialties; but such adaptation seems worth trying only by specialty companies that serve or operate in the textile-finishing industry. The consensus seems to be that the total potentially realizable market for oilseed proteins in this use is relatively small. In general, those applications for which proteins might be best suited are now using, or moving rapidly toward, synthetic resin compositions.

Shade cloth from which window shades are made, has represented the principal textile-finishing use for proteins; its outlook seems too poor to warrant any considerable direct effort toward this use on behalf of oilseed proteins. A larger present use (1 million pounds of casein and oilseed proteins per year) is as an undersize for resin coatings, but casein is used principally. Oilseed proteins have apparently obtained only limited acceptance for this use; synthetics are actively and increasingly competing.

Paper Coating

Oilseed proteins have been used in the paper industry in varying quantities for pigment coating, wallpaper coating, insulating-board coating and plying, in adhesives for plying paper and board, and for paper sizing. They have been tried with variable success as adhesive coatings and as clear coatings or over-coatings for paper.

Pigment Coating.—Soy-protein isolate is widely substituted for casein in pigment coating paper and paperboard, for the purpose of binding pigments to the paper stock and to each other. This is much the largest use of proteins by the paper industry—about 14.5 million pounds of soy-protein isolate and 20 million pounds of casein are so used annually. At present, the outlook for use of oilseed proteins in this industry is threatened by latex additions, other synthetics, and starch coatings, which are making inroads in this use. But development of better rheological properties and further expansion in the demand for water-resistant coated paper may be offsetting factors.

Wallpaper Coating.—In coating wallpaper, soy-protein isolate is preferred to casein because of superior rheological characteristics, brighter finishes, and lower price. About 5 million pounds of soy-protein isolate are used for this purpose annually, in addition to 2.5 million pounds protein content of soy flour. Latex is reducing the use of soy-protein isolate; indications are that it may replace as much as one-third of the present use.

Insulating-Board Coating and Plying.—Only about one-tenth of the total 2 to 4 million pounds of coating used in connection with insulating board is now made by the proteins. Soy isolate and casein are used but soy has the largest part of the protein market for this use. Starch is the predominant coating material used, but is not wholly satisfactory. If satisfactory properties are developed in oilseed proteins, they may take over a part of the market now held by starch.

Clear Coatings, Commonly Over-Coatings.—Synthetic resins and related materials are usually applied to get clear coatings, commonly called over-coatings. Shellac is sometimes used, and zein has won some rather small use as a shellac-like material.

Adhesive Coatings.—Soy-protein and especially peanut-protein isolates have been tried as a replacement for dextrins and for animal glues as adhesive coatings on stamps, envelopes, gummed paper tape, etc., but it is not in commercial use.

Paper Size.—Soy-protein-stabilized beater sizing that is rosin-based is used to some extent in the paper industry. There is no basis for estimating the quantity of soy protein so used, but apparently it is small.

Woodworking Glues

Glues for the production of plywood and related veneer products constitute the largest industrial (that is, nonnutritional) use of soy meal other than for the production of soy-protein isolate, coating paper, and wallpaper. The plywood industry uses about 42 million pounds of soy meal annually. It also uses roughly an annual 3 million pounds each of casein and of blood, but uses practically no soy-protein isolate. It has used peanut and cottonseed meals as adhesives, and retains a moderate interest in the former. The production of plywood and related veneer products uses far more glues than does any other part of the woodworking industry.

Soy-meal glues have been losing ground to phenolic resins in their main market—softwood plywood—and they have been losing to urea resins in the production of hardwood plywood. In both instances, but especially in relation to phenolics, the situation has tended to become temporarily stabilized. Research in industry on gluing technology, soy-meal characteristics, and the rheology of soy-meal solutions has helped soy meal to hold its position. The long-term outlook for the production of softwood plywood and trends in the technology of the industry, suggest that soy meal will need more research if it is to hold its ground here, but that such research will be fruitful. The work of the Southern Regional Research Laboratory of the United States Department of Agriculture, on mixtures of oilseed meal and urea (not urea aldehyde resins) may strengthen the position of oilseed meals, especially in the hardwood plywood industry, but this had not yet been evaluated by users who were interviewed in this study.

Other Adhesive Uses

The greatest possibilities in this field for additional use of oilseed proteins appear to lie in connection with solid fiberboard (perhaps a million pounds—one-fourth of the annual potential of 4 million pounds—is now so used) and in spotting thin cork-board inserts on metal bottle caps (a market of comparable size). The adaptation of soy-protein isolate for use in the manufacture of solid fiberboard shipping boxes has been successful, but the more general potentialities of oilseed proteins are in the production of corrugated fiberboard shipping containers, which is the largest market for adhesive. In peacetime, solid fiberboard boxes constitute only 4 percent of the fiberboard shipping-box industry; they are much more important in wartime for tough export containers. Consumption of casein and oilseed proteins as adhesives for purposes other than woodworking approximates 5 million pounds per year; most of this is casein. Consumption here continues to decline, however, as competing materials are improved in quality or are reduced in cost. For many uses, synthetic materials, particularly the vinyls, have proved to be superior in both quality and ease of handling; the better control of adhesive film which they impart frequently means savings in costs. Adhesives based on starch usually are considerably cheaper; progress in starch technology has made starch products increasingly vigorous competitors of proteins, especially in the absence of comparable knowledge on which to build protein developments. Therefore, any really large-scale use of vegetable proteins must be in competition with starch and silicate of soda, used for the manufacture of corrugated board. It seems doubtful that proteins will be able to overcome the advantages of these materials as corrugated-board adhesives.

Multiwall paper bags offer a relatively large market for adhesives, of which oilseed proteins might achieve an attractive minor share, because of their water resistance, if they were developed so they could be applied cheaply.

Miscellaneous prepared adhesives will benefit by oilseed protein research generally, but most of their markets are too diverse to appear to warrant special effort except within that industry or by users.

Water Paints

Consumption of the powder-and-paste type of water paints continues to decline as the resin-emulsion type meets growing consumer acceptance. The business of water-thinned paints has declined somewhat from the peak war and early postwar demands to a relatively stable sales level of $40,000,000; this represents only about 4 percent of the total paint industry. However, technological improvements in the resin-emulsion paint industry are expected to lead to some future growth in the use of water paints.

Synthetic emulsifying agents threaten proteins over the long term, but their current use is limited by their higher costs. About 6 million pounds of casein and 4 million pounds of oilseed proteins are currently used in water paints. The 6 million pounds of casein afford a likely target for further development of soy isolate and corn gluten. Some tendency toward the use of a declining quantity of protein per gallon of water paint may be offset by a gradually expanding market, especially for the latex or resin-emulsion type of paint.

• A moderate further increase (about 1 million pounds) in the use of zein in special markets for spirit varnishes seems probable as application development continues by its producer.

Rubber

The tire-cord dip market which uses proteins (usually casein) to promote better adhesion to the rubber-tire stock, is the most significant use of proteins in the rubber field, consuming about 4 million pounds of casein per year. The magnitude of casein consumption in other latex products is not readily estimated but it is probably about 2 million pounds per year. This makes the total consumption of protein in association with rubber about 6 million pounds annually. Apart from a decided trend toward the use of synthetic resins, particularly for tire-cord dips, these markets are fairly stable and no other immediate shifts in consumption are foreseeable. It does not seem probable that oilseed proteins can successfully compete for these rubber latex markets, unless there are marked improvements in their quality. However, results of semi-fundamental research on oilseed proteins, if undertaken for the larger potentials, may be applied to displace casein (now 6 million pounds currently used) from use in tire-cord dips and in latex adhesives. But as resorcinol resins are tending to displace casein in the making of the tires, the oilseed proteins will have to watch this market carefully.

Plastics

Use of oilseed proteins as resin extenders and fillers for plastics is generally considered to be distinctly unattractive. Blood-phenolic resin combinations in plywood glues, however, suggest some potentialities for oilseed protein research. The limited and declining use of casein for extruded plastics is potentially replaceable by oilseed proteins, but unless based on useful new knowledge about the characteristics of oilseed protein, renewed attempts to secure this market may not be warranted.

Asphalt Products

Printed felt base, as the least expensive of floor coverings, represents a relatively stable industry, using annually roughly 3 million pounds of protein; casein accounts for 2 million pounds and soy-protein isolate the remaining 1 million pounds. The use of asphalt emulsions in roads is also a stable market and one in which the consumption of protein may conceivably be increased. At present, economic considerations have limited such consumption to less than 1 million pounds per year of protein in a crude form. Cottonseed and soy proteins compete with casein, blood, and lignin, for this market.

Miscellaneous Uses

Except zein-based inks, and the possibilities of purified oilseed proteins for use in photography, other miscellaneous uses of oilseed proteins do not appear to warrant special effort. Both of these, however, would potentially provide substantial specialty markets, requiring considerable research.

Supplies of Oilseed Proteins

Except for peanut protein and wheat gluten, supplies of the oilseed proteins on which development has been based so far seem to be ample in comparison with any prospective need. The development of peanut protein in this country depends in part on working out lower costs in the production of the peanuts and providing a large and reliable supply for the regular production of oil and meal, rather than diverting only the surpluses to such milling. The use of wheat gluten is limited by the market for wheat starch, of which it is a minor byproduct. Supplies of casein have been irregular, and most imports have been poor and variable in quality; these facts have helped the acceptance of soy-protein isolate in competition with casein. Current development of soy-protein isolate having several standard rheological characteristics is likely to assist such displacements.

TEXTILES OFFER AN INTERESTING POTENTIAL FOR OILSEEDS

Regenerated Protein Fibers

The term "regenerated protein fibers" as used here means protein fibers which have been manufactured by dissolving proteins in a solvent, extruding them through a die, and subsequently coagulating them to form a filament. The term "regenerated" is intended to distinguish them from "natural" protein fibers, such as wool or silk. It is not wholly satisfactory: some are inclined to think that "synthetic" would be more descriptive. But that term has certain shortcomings also, as the proteins used in preparing these fibers are not strictly synthetic. The disadvantage of the word "regenerated" resides in the fact that many of the protein fibers have been prepared from such proteins as zein or casein which never existed in a fibrous form. Nevertheless the term is used throughout this bulletin as it appears to be a relatively well-accepted definition of fibers of this kind.

The history of regenerated protein fibers goes back several hundred years but their commercial production began much more recently. Apparently the first large-scale production of protein fibers from casein was initiated in Italy in 1935. These fibers were sold there under the name of Lanital. At the same time they were manufactured and sold in Germany under the name of Tiolan, and in Belgium under the name of Cargan. Later, in the United States a casein fiber sold as Aralac has been produced which was used on a substantial scale during the war as a supplement for wool and also as a substitute for hair in the manufacture of felt hats. The manufacture of casein monofilaments (relatively coarse fibers), as an alternative for curled horsehair and curled cattle hair, has been undertaken.

Soy-protein isolate has also been used in the manufacture of fibers[7] In this country interest in this development was noted, and as early as 1939 textile fibers made from soy protein were exhibited. The soy-protein fibers manufactured in this country have been on an experimental basis and have not reached commercial production. The pro-

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[7] Hereafter in this bulletin the term "soy isolate" will be used in most cases rather than "soy-protein isolate." Other vegetable protein isolates will be handled in the same way.

duction of textile fibers from soy protein was noted in Germany as early as 1940.

Peanut protein has also been used. Courtaulds, in Britain, has been experimenting with this material for a considerable period and it is thought that they have peanut-protein fibers in production on a pilot-plant scale. Of more immediate importance is the work, also in Britain, of Imperial Chemical Industries, Ltd., which is now producing peanut-protein fibers in a pilot plant on a small scale, and expects to have them available in commercial quantities in the near future.[8]

Zein (corn protein) is currently being used in the production of fiber and is sold commercially under the trade name of Vicara.

Reasons for Interest.—This considerable interest in the production of fibers from proteins, particularly at the present time when increasing numbers of synthetics are becoming available, raises fundamental questions concerning their potentialities. The early development work probably was initiated in the hope of producing a low-cost fiber similar in its properties to silk. More recently, work has been directed toward the development of a fiber which might be used economically and satisfactorily as a blend or other type of supplement for inadequate supplies of wool. This interest has been increased by the fact that wool production in the United States, during recent years, has averaged less than 75 percent of the average clip for the 1930's. Moreover, despite continued growth in world population and in world consumption of textiles generally, the world production of wool has expanded very little beyond the average for the 1930's and world production of fine wools has declined slightly.

Properties.—The rather meager physical data that are available indicate that regenerated protein fibers have several features that tend to offer market opportunities:

(1) The regenerated protein fibers can be produced in essentially any desired diameter. This is especially important, as fine wools are becoming increasingly scarce. Similarly the fibers can be produced in any desired staple length.

(2) Like natural protein fibers—such as wool and silk—regenerated protein fibers are resilient. The following tabulation indicates that, under long-term loads, regenerated protein fibers tend to show a much higher degree of recovery than do such cellulosic fibers as sisal.

	Resiliency at 50 percent R. H.[1] *relatives*
Horsehair	100
50-50 mixture of curled horse hog hair	67
High-grade sisal	33
Wool	80
Casien (casein fiber)	63
Curled regenerated keratin	89

[1] Based on tests recently developed for monofilaments by Arthur D. Little, Inc.

Another convincing demonstration of the resiliency of regenerated casein yarn has been made at the Eastern Regional Research Laboratory, where it has been shown that if casein and rayon yarns are elongated to a similar extent, the casein yarn thereafter returns almost

[8] See footnote 6, p. 8.

to its original length whereas the rayon shows a much higher degree of permanent elongation.

(3) Improved resistance to moths and carpet beetles is a potential property of these fibers. By incorporating mercury salts or other insecticides in the fibers, they can apparently be made completely resistant to these insects. It is expected that other less objectionable agents can be found that will be suitable for this purpose.

(4) In their susceptibility to dyes, regenerated protein filaments are generally similar to wool, and are far superior to synthetics (*8*).[9] Attempts have been made to utilize the dyeability of proteins in viscose rayon by incorporating casein in the spinning dope. Snia Viscosa, in Italy, produced experimentally such a product under the name of Cisalfa, which contained 3 percent casein. Its development was abandoned during the war when skim milk was required for food and was not available for nonessential casein uses. No record of trial in this country has been noted. Possibly this is a potential use for oilseed proteins. A partially hydrolyzed wool product (from scrap wool) has been developed in the United States for this purpose.

So far this discussion has centered about the comparatively good properties of regenerated protein fibers. A considerable number of major disadvantages of regenerated protein fibers are found when they are compared with competing fibers.

Some of the disadvantages may never be overcome entirely owing to the inherent characteristics of the fiber. Some of the inherent advantages of wool, as its warmth, its insulating qualities, its resiliency, and its dyeing qualities, may never be overcome. This is more fully discussed on page 18. However, some disadvantage attributed to regenerated protein fibers which might be overcome by more fundamental research on the protein molecule follow.

(1) Most of the fibers of this type show some color; only casein fibers can be made almost white.

(2) None of these fibers has yet achieved a dry tensile strength equal to that of wool.[10]

(3) The fibers' lack of cystine as found in wool. Some cross-linking agent for regenerated protein fibers might be developed to compensate for this lack. The cystine imparts a high degree of cross-linking and is believed to be responsible in part for wool's excellent resilience.

(4) Regenerated protein fibers are not so resistant to strong sulfuric acid. An important characteristic of wool is its resistance to this acid, which permits it to be recovered for re-use from wastes in which it is mixed with other fibers, particularly cotton. More intimate acquaintance with the protein molecule might lead to correction of this lack.

(5) Regenerated protein fibers tend to putrefy, because of the action of bacteria and fungi. This is particularly true of casein fibers. Treatment by the commonly accepted bactericides and fungicides has been ineffective.

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[9] Figures in parentheses refer to literature cited, p. 119.

[10] The dry tensile strength of laboratory zein fiber has been shown to be equal to the average strength for wool.

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(6) The poor wet strength and related mechanical failure of regenerated protein fibers has been a serious handicap.[11] Substantial progress has been made toward minimizing these disadvantages. The Eastern Regional Research Laboratory has reported the production of stabilized casein yarn that is superior in its wet processing resistance despite its being lower in wet and dry tensile strength than other like fibers which were unsatisfactory. In another connection, a large company has recently found, during work on alternates for Chinese hog bristle, that it is possible to produce regenerated protein fibers which are satisfactory for water base paints but which have approximately the same wet tensile strength as wholly unsatisfactory material.

(7) Regenerated protein fibers tend to be deficient in flexibility. Here again the standard of measurement needs to be re-examined in terms of the use of the fiber in the end product. In the past, brittleness has been measured by the knot test. Fibers having a relatively high tensile strength according to the knot test have been found not able to withstand certain processing operations. This has been traced to the fact that another quality, toughness or impact resistance, is required in the fiber other than the quality necessary to meet the knot test. Therefore it is important that fibers be evaluated with respect to this quality of toughness. If this is done, probably some of the disadvantages of deficiency in flexibility in regenerated protein fibers will be removed.

(8) The scaly structure of the filament surface inherent in the wool fiber gives it some properties that are difficult or impossible to obtain in the smooth fiber surfaces of regenerated protein fibers. This scaly surface makes possible the felting operation, during which wool fabrics under mechanical working become more and more dense. Widely differing fabrics, ranging from blankets to overcoatings, depend on this property for their production. Another property imparted by the scaly surface of the wool fiber is the characteristic "feel" of wool fabrics. Blending of regenerated protein fibers with wool would seem to be essential if the protein fibers are used in fabrics that depend on felting properties.

COSTS.—A number of comments during the interviews indicated the expectation that regenerated protein fibers ought basically to be distinctly cheap. In practice this has not proved to be true, although they have been considerably cheaper than some competing products. For example, at the time this study was made, zein fiber was selling for $0.83 a pound. Casein monofilament was selling for $0.69 to $0.94 a pound, depending on the quantity bought. British interests suggest that their peanut-protein fiber will sell at a price closer to that of viscose rayon staple (then about $0.35) than to that of wool (which was considerably cheaper in Britain than here).

[11] Some of the research work carried on in the field of protein fibers is being measured by some misleading yardsticks. This is not to say, for example, that the water resistance of regenerated protein filaments has proved entirely satisfactory. It definitely has not. But accepted methods of assessing laboratory results directed toward improving these fibers, in using as a criterion their tensile strengths when wet, are misleading and must have discouraged many workers from otherwise attractive approaches. On the other hand, good stiffness—a potentially valuable property which appears to be characteristic of wool and regenerated protein fibers—appears to have been mostly neglected, because of dependence on tests that fail to reveal it.

Large-scale production would tend to reduce all of these prices of regenerated protein fibers but probably not radically. The high cost of protein fibers in comparison with rayon depends partly on the cost of the base raw materials of pure proteins—which was about $0.20 per pound or more compared with about $0.07 a pound for dissolving pulp. The processing operations necessary to produce a spinnable dope are probably not much simpler nor less expensive for proteins than they are for rayon. The subsequent operations on the protein fibers are much more difficult, as the fibers must be tanned or hardened with formaldehyde or some equivalent material. The after-treating processes for proteins are all the more difficult because of the low wet strength, immediately after extrusion particularly. Therefore, the economical processes that have been developed for rayon cannot readily be used. It might be expected that, even after much further development, and the achievement of large-scale production, regenerated protein staple fibers will sell at 40 to 50 percent more than viscose staple, that is (about $0.50 per pound, in terms of the price level prevailing in 1949).

RAW MATERIALS.—The possibility of making regenerated protein fibers from surplus farm products has attracted several of their developers. Production of casein fiber in Italy and Germany, initiated just before World War II, had to be stopped because the skim milk was required for food uses. More recently, when an American company was considering the production of regenerated protein fibers, it was first attracted by peanut protein. An inadequate supply of peanut meal in the United States for large operations, plus the prices that were supported by the Government, raised its costs to an uneconomic level. So the company used zein instead. The question has been raised: Could enough zein be made economically if such fiber production should reach even a moderate percentage of the total of our wool consumption? Apparently it could be. Despite the demand for corn gluten for feeds, it appears highly probable that an adequate supply will be provided to meet all foreseeable needs for the production of zein.

Two factors tend to reduce the quantity of casein available for fiber production. First, the only grade of casein that has been demonstrated to be commercially satisfactory for the production of monofilament fibers is the continuously produced grade, developed and produced in this country under the trade-name "New Process Casein." Production of this material is limited. The total quantity produced at present approximates 5,000,000 pounds per year. Second, governmental purchases of dried skim milk during recent years have resulted in an artificially high price for domestic casein, thereby making its use for the production of fibers less desirable than if domestic casein could be made in a free market.

There is, of course, the possibility of using imported casein. Argentina is by far the largest exporter of casein but this is generally of poor quality, as it contains a good deal of dirt from being dried in the open. As it is mostly self-soured, the coincident bacterial decomposition tends to degrade the protein molecule. Production of casein of better quality, in Argentina, appears improbable in the foreseeable future. Among other foreign sources for casein, only two are of present interest for this purpose; both are now small.

Casein from New Zealand is of excellent quality; after a minor treatment, it can be made acceptable for use in fiber production. Casein from the Netherlands is said to be of very high quality for paper coating, but does not yet appear to have been evaluated for fiber production in this country.[12] The possibility of using either or both is important should the consumption of casein fiber expand rapidly, for the expansion of production of continuous-process domestic casein cannot be counted on. Also the price for casein from the Netherlands or New Zealand, duty paid, was about $0.02 per pound less than the price of good domestic casein, when this study was made. This lower price might be a determining factor in establishing casein fibers, particularly when casein is trying to establish itself in fields now dominated by other and slightly cheaper fibers. Moreover, this spread in price may increase if the demand for domestic New Process casein increases.

Cottonseed protein isolate is under trial as a possible substitute in monofil production, for such uses in which its color is not a limitation. Byproduct keratin (such as is obtainable from wool waste, feathers, horns, hoofs, etc.) is also being worked with for this purpose.

Comparison Between Properties of Wool and of Synthetic Fibers

As one of the purposes of the development of synthetic as well as other fibers has been to produce a fiber that is a satisfactory supplement for wool, it is useful to know the desirable features in wool which might conceivably be found or developed in such fibers. The one most often cited is that wool fabrics have warmth characteristics not found in materials made from any other fibers. This is generally accepted, but the reason why wool is warm is not well understood. For example, for a long time it has been believed that the warmth of wool is due mostly to its ability to absorb moisture, thereby removing the moisture from the skin, and eliminating the cold, clammy feel which is characteristic of some less absorbent materials. Nylon, for example, is known to be cold, and its coldness was believed to be due to its hydrophobic properties. But more recently Orlon is becoming available, and Orlon is generally accepted as being a warm material, compared with nylon. Yet Orlon is at least as hydrophobic as nylon. Apparently no good explanation is known for this difference between the two materials; hence the warmth of wool is all the more difficult to explain.

Another explanation is that wool, because of its highly crimped character, is a better insulator, therefore material made from it feels warmer than other materials. This is questionable. Both nylon and Orlon have been supplied to textile manufacturers in crimped form. Yet material made from crimped nylon, at least, is not warm. Therefore on the basis of the only good physical evidence that can be determined in the laboratory, it appears that the characteristics of wool which make it a warm fiber are not well understood.

Warmth is not always desired in materials that use wool. Wool is used in summer suitings, for example, for its resilience and other advantages, rather than for its warmth. Since 1947, the percentage

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[12] Casein fibers have recently been developed in the Netherlands, presumably using similar casein.

of summer suits made almost entirely of rayon, nylon, or cotton, has increased very greatly (table 2). Technological improvements in rayon and the supply-price situation for wool are among the major causes.[13] In 1949, summer suits constituted 19 percent of all suits cut, and about twice as many separate dress and sport trousers were cut as suits of all types.

TABLE 2.—*Percentage distribution of fibers in summer suitings, annual 1946–49, first 8 weeks, 1949 and 1950* [1]

Item	1946	1947	1948	1949	First 8 weeks: 1949	First 8 weeks: 1950
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Summer-weight suits:						
25 percent or more wool	72.2	72.5	66.2	52.0	64.7	50.6
Rayon and nylon	} 27.8	20.0	24.0	} 48.0	35.3	49.4
Cotton		7.5	9.8			
Separate dress and sport trousers:						
25 percent or more wool	54.7	61.7	60.3	51.2	48.7	45.0
Rayon	26.1	24.5	29.3	40.2	39.7	49.0
Cotton	19.2	13.8	10.4	8.6	11.6	6.0

[1] Men's Apparel, (M67B), (*21*).

Resiliency is a property of wool that is as important as its warmth. Resiliency is its ability to return to its original shape after being stressed during considerable periods. A familiar everyday example of this characteristic is the ability of wool fabrics to resist wrinkling. This characteristic is well recognized; there is no question as to its importance. But there are actually little or no physical test data to measure this quality. Most of the physical tests which have been carried out have involved a relatively rapid degree of loading and unloading.[14] In these tests, cold flow does not come into play to the extent that it does in many practical applications. Under these unsatisfactory test conditions many fibers will appear to be relatively equivalent. Yet, in fact, the ability of wool to resist creasing when loaded for long periods, particularly at relatively high humidities, does distinguish it from all of the other more common fibers. For example, although nylon is now being mixed with wool in paper-mill felts to increase resistance to wear, it is recognized that its use involves a noteworthy sacrifice in loss of resiliency and springiness.

Stiffness is another physical property of fibers which does not seem to have been sufficiently investigated. Until recently, stiffness has been defined as a function of elongation and load at break. This value,

[13] Although production has tended to shift from wool to rayon, a large proportion of owners of summer suits still prefer wool and wool mixtures to any other fiber. These findings are presented in the national consumer preference studies on men's clothing conducted by the Bureau of Agricultural Economics (*18*).

[14] As recently as April 1948, W. H. Rees (7) described a test procedure in which the recovery properties of various fibers were determined after the fibers had been compressed for 1 minute.

whatever its significance, does not describe the physical property which would normally be thought of as stiffness in textile fibers. For these fibers, stiffness should be measured by ascertaining the force required to bend the individual fibers. When such bending measurements are applied to fibers, wool is shown to be far stiffer than most of the common synthetics, including rayon and nylon.

In table 3, data are shown comparing stiffness values expressed as Young's Moduli and as a function of load vs. elongation.

TABLE 3.—*Value of stiffness in specified fibers, by two methods of measurement*

Fiber	Stiffness	
	Young Moduli in bending [1]	Load vs. elongation [2]
	10 dynes/sq. cm.	*Grams/denier*
Wool	3.37	4
Fiber V (Dacron or Terylene)	8.90	--
Nylon	1.05 (fully drawn)	45 (high tenacity)
Do	.814 (undrawn)	24 (regular tenacity)

[1] Data supplied by J. L. Barach, Alexander Smith Carpet Co.
[2] Rayon and Synthetic Textiles, February 1950 (*30, p. 40*).

It is apparent from these data that these two methods of measurement depend upon wholly different properties. Whereas Young's Modulus measurement shows wool to be upwards of three times as stiff as nylon, the conventional tests show it to be roughly one-sixth to one-tenth as stiff. One large company has found in its laboratories that regenerated protein monofilaments are comparable with natural protein fibers in stiffness (in bending). It is not yet possible to relate the value of stiffness in these terms to the performance of the fibers when woven into fabrics. But the regenerated materials closely approximate wool and other natural keratinous filaments. In this respect they show considerably higher values than the synthetics other than Fiber V,[15] a polymer of ethylene glycol and terephthalic acid development in England as Terylene.

Finally, the dyeing qualities of wool permit it to be colored with a rather wide range of dyes, thus allowing a large variety of shades to be obtained. This quality is particularly lacking in most of the synthetics which, because of their lower reactivity with dyestuffs, are harder to dye and are susceptible to a much narrower range of dyestuffs.

The search for new synthetic fibers has been stimulated by the fact that population (both in the United States and the world as a whole) is increasing faster than production of natural fibers. Moreover, research workers and textile manufacturers have found that blends or mixtures of synthetics with natural fibers are more desirable for some uses than any of the fibers used alone.

[15] Trade name of this fiber, which will be produced commercially in 1952, has been changed to Dacron.

Synthetics are finding a substantial market in satisfying our expanding requirements for more fiber and new types of fiber. Although much of the market for the protein synthetics will apparently be in blends with natural fibers, some of the regenerated protein fibers show promise when used alone.

The continuing emphasis of several of the major chemical companies on the development of synthetic fibers, involving heavy expenditures on research, must not be overlooked—in any projection of the market for fibers. Although often possessing definitely superior physical characteristics of their own, the synthetic fibers have sufficiently different textile properties to cause difficulty in their adaptation to conventional textile-mill technique and consumer application. Therefore, the size of their potential market depends not only on the ability of the fibers to compete in price with cotton, rayon, and wool, but also on improved knowledge by the textile industry in utilizing them to the fullest advantage.

Acrylic fibers are receiving most of the attention among new synthetics on which advanced development or production is especially active. In their staple (nonfilament) form they are expected by their manufacturers to compete in some uses with wool. Orlon, Dynel, and Chemstrand, are all basically acrylic fibers. How active such competition will be depends on the extent of the fabric development and the consumer testing necessary to appraise these new fibers, as well as on their own further development.

Among new nonacrylic synthetics, Dacron is of special interest. Its excellent resilience may lead it to compete for some uses with protein fibers, on a stronger basis than do other synthetics.

Apparel grades of wool are properly considered to be the principal standard of comparison, but in addition to the possible market in nonwool natural protein fibers, a substantial additional market exists for carpet grade wool. During the recent periods when wool markets were relatively normal, 1939–40 and 1947–49, consumption of carpet wool in the United States, scoured basis, averaged about one-third of the consumption of apparel wool. In 1948, after a sharp climb, the consumption of carpet wool totaled 209 million pounds. The market for this wool is smaller than the one for apparel wool and it uses several of the coarser grades of less expensive wools. It is subject to heavy cyclical fluctuations. Yet there is considerable interest within the carpet industry concerning the possible use of regenerated protein fibers, and trial is now being made of fine casein monofilaments as pile. This interest has been accentuated by the increasing price and the decreasing availability of both carpet and apparel wools. Resiliency is considered of great value in rugs and carpets.

Suggested Research on Fibers

This increasing importance of synthetic polymer fibers in the textile market (but still negligible compared with an annual consumption of slightly less than 5 billion pounds of cotton and slightly more than 1 billion pounds of rayon) does not necessarily represent an obstacle to the promotion of a protein fiber. Improved knowledge of blending both natural and synthetic fibers in staple form will be necessary to advantageous promotion. The advantage of combining the strength of the synthetic nylon, and the soft, resilient, economic wooliness of Vicara, for example, has attracted some interest. It is reasonable to believe that the advantages of cost and availability of the raw material of the fibers based on oilseed proteins indicate an excellent potential market. Research effort and expenditure comparable to that which has resulted in the continuing development of acetate and viscose rayon, nylon, and now acrylic fibers, will probably be required.

Most of the suggestions for research received by the Regional Research Laboratories, aimed at making regenerated protein fibers more acceptable for textile use, have been rather general. Predominantly, they request that more fundamental studies of the structures of proteins be conducted, not only on extracted material but also on the proteins as they naturally occur, to learn to what extent they are altered in the extraction process. The value of such work, of course, would not be limited to the production of fibers. The work of the Western Regional Research Laboratory on physical-chemical fundamentals is highly regarded by industrial research workers. Technical men working in this field want to have the laboratory's current related work on wool coordinated with corresponding work on proteins for regenerated fibers.

The determination of the structures of proteins, their structures after regeneration in fibers, and the relationship of their structures to the physical characteristics of the fibers so made, is considered to be extremely important. For example, one interviewed scientist who is exceptionally well-informed in this field, believes that little of the work done on producing fibers from soy-protein isolate would have been undertaken had data like these been adequately available at the time. The work would probably have been directed either to more promising proteins or to achieving basic modifications in the structure of soy protein.

Fundamental work requested of the United States Department of Agriculture includes physical studies to find means for transforming globular to fibrous proteins. The work at the Southern Regional Research Laboratory on increasing protein molecular weight or otherwise altering physical-chemical characteristics by linking together two or more protein molecules, or protein and nonprotein molecules, is of general interest, as is its proposed study of the course of the reaction between formaldehyde and proteins, and of other "tanning" reactions, using radioactive carbon. It has also been suggested that proteins be carefully broken down, possibly even to ultimate amino acids, and that the parts then be synthesized to high polymers along lines likely to give, for example, high molecular weight and linearity.

Other suggestions of more immediate commercial importance have been made. One is that a careful study should be made of those fields into which protein fibers will best fit. It is generally considered that the use of Aralac in poorly suited fields made textile manufacturers wary of adopting any of the newer regenerated protein fibers. To some extent useful data can be obtained by practical mill trials but there is a need for more basic objective information concerning the properties of fabrics (to replace such subjective terms as "hand"), and for facts in regard to these fibers as to the uses of such qualities as to resistance to abrasion, resiliency, stiffness, strength, crimp, surface characteristics, and other properties.

A general start on this work has been made at the Textile Research Institute, at Princeton, N. J., and in other laboratories—some of them commercial. But the supplementary efforts of the Regional Research Laboratories, emphasizing certain aspects of the regenerated protein fibers, is considered to be of substantial potential value by technical men in this field. Work in developing special fabrics employing these fibers in appropriate mixtures has also been suggested, coupled with qualitative and quantitative studies of the textile market involved.

Warp Sizes a Limited Market

Warp sizes offer a potential market for oilseed proteins of about 12 million pounds a year. They would be used in weaving continuous filament rayon (including acetate, viscose, and cuprammonium) instead of some of the gelatin, glue, resins, and casein, now used for this purpose. This estimate assumes their use at the same rate per unit of warp sized as the gelatin now generally used. Possibly smaller additional quantities might be developed for use in size compositions employed for such synthetic fibers as nylon.

Considerable experimental work has been done in this field, mostly when price relations were more favorable for oilseed proteins. This entire market is now subject to active competition from synthetics but oilseed proteins still have a chance to compete with synthetics on the basis of price.

Warp sizes function as temporary tough films used to protect threads when they are woven into fabrics. Cotton mills use starch for warp sizes, because cotton endures the hot water, at about 200° F., necessary to wash out these sizes completely. But rayon fabrics cannot be subjected to a temperature above 150° F., which is not high enough to remove starch. Rayon staple threads are sized with starch, but are desized with enzymes. Producers of filament rayon continue to use protein or resin sizes. Starch sizes do not form sufficiently strong continuous films to bind together the individual fibers in threads and form a smooth surface, especially in view of the residual oil on filament rayon surfaces.

Approximately 125 million pounds of starch are used as a warp size for cotton and rayon staple. The equivalent of about 12 million pounds of glue or gelatin are used as a warp size for filament rayon. Most of this market consists of sizes for acetate filament. A little more acetate than viscose filament is used; acetate warps are often filled with viscose; and a given quantity of acetate uses roughly three times as much size as an equivalent quantity of viscose.

Although small quantities of sizes, based on polyvinyl alcohol or other synthetic polymers, or using casein, are used for nylon filament threads and threads of other synthetic fibers, no really suitable size has yet been found for these threads. The main difficulty with nylon is that the fibers are so smooth that sizes do not stick to them. In addition, the nylon fabrics have to be desized in mild and tepid solutions.

The main development in warp sizing during recent years has been the introduction of synthetic resinous materials as sizing materials for continuous filament rayons. Polyvinyl alcohol was introduced some years ago but its use has been limited by its price ($0.76 per pound). Maleic anhydride resins were introduced about 3 years ago. Their sodium salt, sold as Stymer S, already accounts, probably, for one-fifth of the filament rayon market: it is used predominantly on acetate warp. It could possibly get half this market within 3 more years, but if prices for proteins drop substantially, most of this market will probably revert to them. This possibility gives oilseed proteins an interesting potential.

Only 60 percent as much Stymer S as gelatin is used in a sizing formula; both formulas give the same "mileage" on the warp. Hence (at $0.44 per pound) $0.264 worth of Stymer S is required for mileage equivalent to gelatin's, for which most mills pay about $0.25. The real advantages of Stymer S are operational. It permits saving the yarn that is now wasted during washing down, and saving time on the slasher. It does not change weaving efficiency, which is already extremely high in well-run mills. Some mills are reported to consider they can afford to pay twice as much for Stymer S as for gelatin, but this does not seem typical. Stymer S, unlike polyvinyl alcohol, has desirable anti-static properties.

The Stymer S price ($0.44 per pound) is lower than earlier prices, and is made possible by the economies of larger scale of production. Moderate further reductions in price are expected by the manufacturer as production continues to increase. On the other hand, apart from this, prices of Stymer S are not likely to be able to decrease substantially if gelatin prices decrease. The manufacturer of Stymer S expects to be able to hold this market only so long as prices of gelatin remain somewhere near or above the level that prevailed in the spring of 1950.

Although some textile mills make up their own warp-sizing mixtures, most of those that use protein sizes seem to buy blends from companies that specialize in their production; these blends require only the addition of water and heat in the mill. These size-manufacturing companies provide a good deal of technical service to the purchasing mills. For cotton sizes these companies provide size blends, to 1 pound of which the mill adds approximately 10 pounds of starch and 100 pounds of water. The blending materials include plasticizers. Sizing materials for rayon may include a blend of bone glue and gelatin and sometimes some casein. When casein is used, an alkali such as borax is used to permit its solution at a low pH, and preservatives are added to prevent spoilage of gray goods (from which the size has not been removed) in storage.

Reports collected during the interviews on the relative use of glue and gelatin in protein sizes are conflicting. Most mills that compound their own sizes are believed to use gelatin. Casein is sometimes used straight, as well as in blends with other proteins.

The price of the glue and gelatin normally used for warp sizing ranges from a 19-cent bone glue to a 33-cent gelatin. Most of the gelatin (usually 250 gm strength) sold for this purpose was bought, in early 1950, at around 25 cents. But for some specialties, the sizing of velvets, for example, a stronger grade of gelatin is required; this sells up to 40 cents per pound. Warp sizing represents one of the largest uses for industrial-grade gelatin.

Bone glues as cheap as $0.16 per pound are used to some extent, especially in blends with better materials, but are rarely regarded as resulting in a net saving. During World War II, when gelatin was extremely scarce, casein was used as a substitute by many mills, usually in specially blended formulas sold under trade names by specialty sizing houses. In some of these formulations, casein was the only protein, but in others it was used as an extender for gelatin. As the technique of using it to best advantage was difficult to establish, the bulk of the market has reverted to gelatin or has shifted to synthetics. But at least one large weaver of rayon learned to use casein skillfully and has continued its use in definite preference to gelatin. Other mills would probably use it if they learned how to do it well. This mill has recently changed to maleic anhydride but will probably change back to casein if casein's price drops substantially.

Soy isolate has been given considerable development for this use by warp-size manufacturers for rayon, in cooperation with all present and at least two prospective commercial producers of soy-protein isolate. In meeting this rayon sizing market there are several difficulties. The size must be applied at a pH not greater than 8; it must wash out easily in lukewarm water. On both of these points glue and gelatin have an advantage. Degraded products of soy isolate tend to be insoluble in water, whereas those of glue and gelatin are water-soluble. Then the films formed on rayon by sizes that are based on soy protein are relatively poor in flexibility and they generate too much heat of friction during the weaving. Soy-isolate sizes are said to be inferior to gelatin size in resistance to abrasion. Nevertheless, considerable interest remains in their potentialities, especially if basic research is done to improve the film-forming properties of soy isolate. One qualified producer considers that, in the most modern mills, soy-isolate sizes are distinctly promising. Except for a very few such mills, however, the industry requires greater abrasion resistance than is now available in soy-isolate sizes.

One size company gives three main objections to soy-isolate:

(1) It would not solubilize in mild (low pH) solutions.

(2) It tended to gel in a relatively short time after dispersion, and would not re-dissolve. A soy-isolate paste sizing turned to a useless insoluble gel in the containers within a few hours.

(3) Even though all of the size washes out, if goods turn out to have an off-color, it is likely to be attributed to the size material if it is less colorless or less white than is customary.

Peanut-protein isolate has been of interest because of the possibility that it might be applied at a relatively low pH. But it tends to set up an irreversible, insoluble gel, difficult to remove from the thread.

Soy and peanut isolates, when accompanied by a suitable preservative, do not putrefy during storage (gray goods may be held in storage for considerable periods before the size is washed out and the dyeing takes place). Casein and zein are less satisfactory in this respect.

Permanent Sizes Not Promising as Outlet

Among the many types of textile finishing operations, none appears to offer a potential market for which any available oilseed proteins are worth development, as such, by the Regional Research Laboratories. As a byproduct of developments for other purposes oilseed proteins may ultimately find a place in some part of this market, but synthetics are making marked progress throughout. Use of proteins is declining in sizing for shade cloth and is threatened in the making of undersizes for resin coatings.

SHADE-CLOTH SIZE.—For a long time the only part of the permanent textile-size industry, or textile finishing in general, in which casein or oilseed proteins were a substantial factor was in connection with shade cloth. Possibly 300,000 pounds of casein are now used annually, blended with carboxymethyl cellulose (CMC) or gums, to coat 10 to 12 million yards of shade cloth, at a cost of 12 to 14 cents per pound of size, or 1.5 cents per yard of cloth. Casein provides better and more uniform quality, but glue is cheaper per yard of cloth sized, as it occludes into the cloth most of the water in which it has been dissolved, retaining this for several years. Glue is used exclusively in the production of hand-sized shade cloth and in such machine-sizing plants as lack facilities for festoon drying. Perhaps 500,000 pounds per year of glue are used.

In addition to sized shade cloths, there is a much larger production of cheap, low-count, filled shade cloth—filled with starch-bound clay, whiting, or talc—to give the appearance of body. The high operating temperature (240° F.) reached in its production precludes the use of glue. An increasing proportion of shade cloth is filled instead of sized.

But the outlook for conventional shade cloth, in general, is extremely poor. Principal producers expect a continued marked decline in the market as it is being displaced by Venetian blinds, draw curtains, and shades made of coated paper, resin-coated cloth, and plastic sheets.

Rapid decline in the production of conventional sized shade cloth has led to a general loss of interest in alternatives to casein or glue for this purpose, unless they promise rather marked improvement. Therefore, it is only of slight interest perhaps that soy and peanut isolates and zein have been tried in shade-cloth sizing, in a variety of formulas. All lacked sufficient flexibility; they broke under repeated flexing. The zein lacked sufficient water-resistance to make an easily cleanable shade cloth unless given a formaldehyde treatment that was objectionable to the employee doing the work. Zein is still of interest for some small specialty uses. Color has been a principal deterrent to use of oilseed proteins. This has been especially true when soy flour has been tried, instead of the more customary isolate.

Some protein-stabilized water-thinned paints are used to paint paper to be used for shades, but usually oil paints are used.

UNDERSIZES.—Resin coatings for shade cloth and other specialty cloths are commonly applied over an undersize that helps to bind the resin to the fabric and reduces the quantity needed. This is now the largest fabric-finishing use for casein. It is estimated by the industry that about 1,000,000 pounds of casein are used annually for this purpose. Recent trials with soy isolate by a competent mill resulted in inferior bonding strength, hence poorer "hand" and color, than when casein was used. Polyvinyl alcohol, despite its higher price, is now actively threatening this use of casein. Styrene resin emulsions, though still in the development stage, also appear to be promising.

However, another mill does use a 50–50 blend of casein and soy isolate, probably as an undersize, though possibly also as a conventional size for shade cloth. It prefers the quality of this blend to the size obtained with straight casein.

CARPET SIZE.—About 10 million pounds of starch and 1 million pounds of synthetic resin are now utilized in conjunction with clay to size carpets or actually to stiffen them. Both are figured on an anhydrous basis. Many hydrophilic materials—such as alginates, carboxymethyl cellulose, or vegetable gums—could be used but starch has an advantage in price. As casein has been unsatisfactory, technically as well as economically, no effort has been made to adapt vegetable proteins to this application. There is some tendency toward use of styrene-butadiene latex.

PAPER COATING INCREASING IN USE

Coated paper (or pigment-coated paper as it is sometimes called) represents a substantial proportion of all paper produced (roughly 30 percent of paper and 17 percent of light folding box-board). Most paper is coated in order to up-grade a relatively low-cost base sheet to a higher grade of paper capable of providing good reproductions of printing-plate designs, especially of half-tones. In addition, paper and particularly paperboard are coated to provide the paper with varying degrees of resistance to water or grease.

Pigment coatings are mixtures of pigments and an adhesive, together with such minor ingredients as are needed for the particular end use. The adhesive serves to bind the pigment particles to each other and to the base paper stock.

The uses of coated paper are many and varied including use in magazines and books, advertising brochures, posters, labels, specialty wrapping papers, and box covers.

Coated paperboard is manufactured primarily for making folding and set-up paper boxes, such as are used to package individual units of consumer goods, and which are in turn packed in kraft container-board shipping cartons. Some of these cartons are now being coated also, to facilitate the printing of advertising displays on them. This is a new and promising market, for which several coating materials are being tested.

Materials used as paper-coating adhesives principally include starch, glue, casein, soy isolate, and a synthetic latex. The end use of the coated paper dictates the choice of the coating adhesive since the adhesives made from these materials differ in such basic properties as binding power, waterproofing ability, color, flexibility, cost, and ease of handling.

THE CONSUMING INDUSTRY

The paper industry is so large that any material entering into the production or finishing of paper is used in large quantities. Fine papers are produced to receive printing inks satisfactorily, and better printing can be done on coated than an uncoated paper. The base stock can be rather inexpensive since it acts mainly as a carrier for the coating material, but adds strength characteristics to the finished coated sheet.

The production of coated papers in 1949 was approximately 1,500,000 tons. The trend in production has been increasing at a rate of about 200,000 tons per year, since World War II. In addition, the production of coated box-board was about 500,000 tons in that year. The box-board coating used only about 5 percent of the total paper-coating adhesives, for it has much less surface area and coating, per ton, than do the coated papers. Box-board constitutes a good market for protein adhesives as about 25 percent of the total adhesives going into box-board coating comes from protein.

Those in the industry who were interviewed in this study expect the upward trend in the use of coated papers to continue. Some of this increase is expected to come from increased demand by advertisers for better printing papers and from an expansion of printed advertising. Some think there is a possibility that even some newsprint may be coated in the future. The expansion of the market for coated papers is being greatly aided by the improvement and increasing use of machine-coated papers, which are cheaper than the off-machine coated papers and yet are satisfactory for most uses.

Methods of Paper Coating

The two processes by which pigment-coated papers are coated are known as off-machine coating and machine coating. Paper has been coated by the off-machine or conversion process since early in the century; the machine-coating process is relatively new, having been introduced in the middle 1930's. The off-machine coating operation comprises applying to finished paper, supplied in rolls, a coating of pigment and adhesive. The coating is applied as a water dispersion and is subsequently dried to remove the water. The drying must be done carefully to prevent the coated stock from curling; and slowly, so that the partially dry coating will not stick to the drying cans that are normally used. The coating has been applied by one of several methods, including knife coating, roll coating, and brush coating. In the last few years a new process—air-knife coating—has been introduced. It is increasingly used. It is different from the other methods in that the coating is spread or leveled by impingement on the wet coating of high-velocity air from a narrow slit. This has the advantage of providing a uniform coating containing no streaks.

The sheet that has been coated by any of these methods is later dried, and the surface is then finished by supercalendering. This operation compacts the surface and tends to level the high spots and fill the valleys. It provides a very smooth and more-or-less glossy surface to receive print.

Machine coating is carried out by coating the paper as it is being made on the usual paper machine. It is necessary merely to provide a coating head on the paper machine, located just ahead of the can driers. Machine coating eliminates the extra handling of off-machine coating, and applies the coating to the full width of the sheet as made. Until recently only starches have been commercially successful as adhesives in machine-coating paper but recently limited success has been obtained using soy isolate.[16]

[16] A recent publication (10) describes work on the adaptation of casein to machine coating. The usual difficulty, low solids content of the coating mix, apparently has been overcome by the use of sodium sesquisilicate, a compound which modifies the complicated rheological properties of the coating mix to permit high-solids coating in a satisfactory way. High-solids content is always desirable to reduce the cost of evaporating the liquid part of the coating. For machine-coating, in which the coating is applied to a sheet of paper that is already wet, it is essential.

COATING MATERIALS.—Animal glue was the adhesive used in early paper coatings, but it has been largely replaced by casein because of casein's better color and its water-proofing ability. Casein was of predominant importance until recent years; but improvements in starch, the application of soy isolate, and the development of a synthetic latex, have been responsible for a decided decrease in the market held by casein. At present, starch accounts for about 75 percent of the paper-coating adhesive in use. Starch, so far, is used preponderantly in machine-coating, most of which has developed at the expense of noncoated paper.

Synthetic materials are beginning to enter this market. Although only synthetic latex is now being used as a paper-coating adhesive, it is the feeling of many of the paper-mill technical personnel that there is a real opportunity in this field for manufacturers of such materials. The present material is known as Dow 512K latex. It is a high styrene copolymer with butadiene, sold at about 45 percent solids content. It would not be surprising to find an equally satisfactory material among the wide variety of synthetic polymers available today. In addition, there are many possible copolymers not yet available commercially. At least one well-informed technical director thinks that the copolymer field is the most promising of any in which to find a new, different, and improved paper-coating adhesive.

The styrene-butadiene co-polymer latex, now being used, is only one of several latices which might be adapted for this use. The results of experimental work conducted with polyvinyl alcohol have been extremely encouraging from a technical viewpoint, as its binding power is exceptionally good, it can be applied in very high solids contents, and it is easily waterproofed. Its use on an appreciable scale has been prevented because of its cost—$0.76 per pound. Although some reduction in price may accompany the completion of new facilities for production, it seems improbable that the price will decline to the $0.25 to $0.40 per pound that is estimated in the trade as necessary to obtain a substantial market in paper coating.

Hydroxyethyl cellulose is occasioning more current interest than any other synthetic material now considered for paper coating. A special type has been developed for this use. Industry research workers consider it, pound for pound, to be three times as effective as starch in binding power and twice as effective as casein. It is priced at $0.30 per pound for the pilot quantities used in current trials, but it is anticipated by the developer that it will ultimately be sold at an appreciably lower price. One of the companies planning its production thinks there is a fair chance that, after a few years, its level of production will approximate 40 million pounds—equivalent to 80 million pounds of casein or 120 million pounds of starch.

CURRENT AND POTENTIAL POSITION OF PROTEINS

In contrast to the prewar paper-coating situation, which casein dominated, having a prewar peak annual consumption of 40 million pounds, it is now estimated by the industry that starch accounts for roughly three-fourths of the total weight of paper-coating adhesives, and soy isolate and latex account for a substantial share of the remainder.

Table 4 gives estimated figures based on interviews with men in the industry for the use of various adhesives in coated papers, for the year 1949.

TABLE 4.—*Estimated quantity and value of adhesives used in coated papers, by kind, 1949*

Kind	Quantity		Value	
	Actual	Percentage of total	Total	Cost per pound
	Million pounds	*Percent*	*Million dollars*	*Dollars*
Starch	103. 5	72. 2	5. 2	0. 05
Casein	20. 0	13. 9	4. 4	. 22
Soy protein	14. 5	10. 1	2. 8	. 19
512K latex (solids)	5. 5	3. 8	3. 2	. 58
Total	143. 5	100. 0	15. 6	----------

Estimated by Arthur D. Little, Inc., from numerous trade sources interviewed and literature reviewed.

Although all proteins account for less than one-fourth of the weight of all paper-coating adhesives, they account for about 45 percent of the dollar value. These data should be distinguished from those which also include adhesives used in wallpaper coating. Sources which estimate total protein consumption in this industry at as high as 40 million pounds apparently include wallpaper and wallboard.

TRENDS IN PAPER COATING

In order to compare the competing products for the purpose of analysis it was assumed that the price relationships between the various materials would remain the same; that no new materials would enter the field; and that no substantial changes would occur in present materials.

Under these assumptions it is believed that:

1. The use of starch will continue to increase as its development continues and as more machine-coated paper is made.

2. The use of proteins as adhesives will be limited to those materials which require a greater degree of waterproofness than is obtainable with starch coatings. The volume of proteins used in future years will probably decline moderately from the 1949 level. In past years, relative declines in the use of proteins have been offset by marked expansion in total production of coated paper. Future expansion of coated-paper production will probably not keep pace with declining proportionate use of protein. However, it is possible that increase in the use of offset printing, hence of moisture-resistant paper, may be more rapid than the displacement of protein by starch and synthetics.

3. The use of soy isolate will continue to increase moderately at the expense of casein, as more manufacturers who prefer its relatively

lower and more stable price, and its uniformity, find it to be roughly equal to casein.

4. The use of products such as Dow 512K latex will continue to increase, because of its ability to up-grade starch coatings and to provide a more flexible casein or soy isolate coated sheet.

The above situation could be changed materially by changes in the price of the several materials, by changes in the properties of the materials, or by the entry of new materials into the field.

The effect of such changes on soy isolate may be suggested as follows:

Relative reductions in prices are generally considered to be more likely for synthetics, for casein (during the next few years), and for starch products, than for soy-protein isolates. Technical advances in the production of the relatively new synthetics may tend to reduce their prices to the paper-coating industry. Prices of casein have fluctuated erratically since World War II and the quality of imported supplies has been variable. Improvement in their quality and decrease in price may be expected. Starches used in paper coating have been made from relatively high-priced raw materials and these prices may be expected to decline somewhat in the next few years, according to the views of those interrogated.

Improvements in the properties of all products are expected by research men. Synthetics and specially modified corn starches are new and are subject to further active development. Casein of greater purity and uniformity, comparable to U. S. continuous process grade, may become more widely available from foreign sources. Improvement of soy isolate is continuing, notably toward the development of rheological properties that will permit the use of higher solids coatings.

Development of casein and oilseed protein isolates to permit their efficient use in machine coating appears to be their best opportunity to share in the further expansion of this field. The extent of the market so opened depends on future increase of machine coating, increase of offset printing, on relative costs, and on the progress of other materials toward providing water-resistant coatings at moderate costs. The low cost of corn starch is a constant challenge toward improving the water-resistance of its coatings by its modification, and its use in combination with synthetics and other materials. For example, latex additions help to improve the water-resistance of starch coatings.

About 15 percent of the publication grades of coated paper are used for off-set purposes, for which water-resistance is of special importance. This percentage is generally expected to increase substantially over the years.

New materials, especially synthetics, could alter future trends decidedly. The possible use of synthetic polymer latices, other than Dow 512K latex, is a distinct possibility. So far as can be learned, relatively little attention has been given to such materials. As noted above, a new coating process using hydroxyethyl cellulose is rather promising.

Uses by Types of Coated Stock

Several principal types of coated paper and related products, their production, and their use of coating adhesives, are shown in table 5. These types are:

953359—51——3

1. General publication grades. They include magazine and much book paper. They constitute the largest market for paper coating. Practically all machine-coated paper is directed toward this end use. Some off-machine coated paper is also used in books and magazines, including some which is protein-coated. About 1,100,000 tons of machine-coated paper were produced in 1949.

2. Distributor grades. These are sold through dealers, normally without the end use being known in advance. They are still usually off-machine coated. As the end use is not known, and many end uses require water-resistance, these coatings are customarily made to be water-resistant. This requires the use of casein or soy protein as the binder for the coating. About 400,000 tons of such papers were manufactured in 1949.

3. Coated box-board. This must normally be water-resistant, as its end use is often unknown when it is coated, and most uses require water-resistance. Hence proteins are normally used as the adhesives. Approximately 500,000 tons of coated box-boards were produced in 1949, out of about 3,000,000 tons of folding box-board manufactured.

4. Miscellaneous stock. This includes stock for calendars, box covers, posters and illustrations, labels, tags, and Bristol board. The stock is usually coated, with protein as the binder.

TABLE 5.—*Estimated production of coated paper and coating materials used, by type, 1949* [1]

Item	Paper		Folding box-board [2]	Miscellaneous stock	Total adhesives used [3]
	Publication	Distributor			
	Tons	*Tons*	*Tons*	*Tons*	*Tons*
Production	1,100,000	400,000	500,000	--------	--------
Coating materials:					
Coating	220,000	80,000	25,000	6,700	--------
Adhesives	55,000	12,000	3,750	1,000	71,750
	Million pounds [3]	*Million pounds* [3]	*Million pounds* [3]	*Million pounds* [3]	*Million pounds* [3]
Starch	101.5	1.5	0.5	(4)	103.5
Casein	1.5	13.0	4.0	1.5	20.0
Soy isolate	2.0	9.0	3.0	.5	14.5
512K latex	5.0	.5	(5)	(4)	5.5
Total	110.0	24.0	7.5	2.0	143.5

[1] Exclusive of wallpaper, which uses about 5,000,000 pounds of soy protein isolate.

[2] Including boxcover paper stock (that is, coated paper used to cover uncoated box-board box covers).

[3] Dry weights.

[4] Under 100,000 pounds.

[5] 100,000 to 500,000 pounds.

Estimated by Arthur D. Little, Inc., from numerous trade sources interviewed and literature reviewed.

Cost of Coating Compounds

One reason given for the increase in the quantity of paper being coated is that coated paper is cheaper than uncoated paper of the same weight. Partly for this reason, as well as for the better printing which coated paper permits, some technical men in the industry expect that even newsprint may be coated ultimately; this would use a starch base adhesive. Most newsprint used in this country is imported from Canada; a tariff on any paper that contains more than 3 percent ash now effectively prevents the entry of coated paper from Canada.

An examination of a typical formula for a paper-coating compound will illustrate the major part played by the adhesive in the total cost of the compound. The following formula is representative of those used for good water-resistant paper coatings, although it uses a little more pigment per unit of binder (casein) than the average for the industry (table 6).

Table 6.—*Quantity and cost of compounds for coating 5,000 pounds of paper, by a typical casein formula*

Formula and material	Quantity	Cost	
		Per pound	Total
	Pounds	*Dollars*	*Dollars*
Casein:			
Coating clay	720	0.01	7.20
Precipitated chalk	200	.02	4.00
Casein	150	.22	33.00
Borax	18	.04	.72
Caustic soda	1.5	.04	.06
Pine oil	1.0	.08	.08
Soap	3.0	.10	.30
Formalin	3.0	.06	.18
Bactericide	.2	.50	.10
Total	1,096.7	.0416	45.64
Soy isolate [1]		.0361	

[1] By substituting for the casein 150 pounds of soy isolate at $0.19 per pound, the cost of the coating compound is reduced to $0.0361 per pound.

Calculated by applying June 1950 prices, derived from trade sources interviewed and from the Oil, Paint and Drug Reporter to a typical high-grade casein formula supplied by an interviewed paper-coating company.

A starch-bonded coating typically is formulated as follows:

Table 7.—*Quantity and cost of compounds for coating 5,000 pounds of paper, by a typical starch formula*

Formula and material	Quantity	Cost	
		Per pound	Total
	Pounds	*Dollars*	*Dollars*
Starch:			
Coating clay	720	0.01	7.20
Precipitated chalk	200	.02	4.00
Starch	250	.05	12.50
Total	1,170	.0202	23.70

Estimated by Arthur D. Little, Inc., based on trade sources interviewed.

Thus we find that representative costs per pound for paper-coating compounds based on the three principal adhesives are as follows:

Casein	$0.0416
Soy isolate	.0361
Starch	.0202

As each of the above formulas is sufficient for coating 5,000 pounds of paper, the cost of coating compound, per ton of paper, is:

Casein	$18.26
Soy isolate	15.86
Starch	9.48

As costs of raw paper range from $0.05 per pound for newsprint to $0.17 per pound for uncoated book paper, the application of these coatings tends to provide a means for producing a given weight of paper at a lower cost of material. The costs of applications are relatively low, as is indicated by the following relationships of quoted prices:

Grade of book paper:	*Cost per pound*
Uncoated	$0.149–0.179
Starch-bound machine-coated	.149– .1665
Protein-bound off-machine coated	.1775– .209

Protein Intercomposition and Other Attributes

Estimates of the share of the protein coatings held by soy isolate range from 25 percent to 50 percent. At present, soy isolate appears to account for about 42 percent of the proteins used as paper-coating adhesives: nearly all the rest are casein. A little glue and a little soy flour are used.[17]

So far as can be learned, no products of oilseed protein that are as yet commercial show any clear-cut technical advantage over top-grade casein, for use in paper coating. Until recently, casein had better color than soy-isolate coatings. This is important, since users of coated papers increasingly accept only materials that provide the whitest feasible coatings. Soy isolates of standard quality are now considered adequate in this respect by most users. The adhesive value of soy isolate and casein are approximately equal. Coating compounds made from them "handle" with about the same degree of ease, and the several rheological properties of such compounds (especially viscosity and thixotropy) are comparable.

As the traditional protein adhesive for paper coating, casein is still exclusively used by some mills simply because they have not gained sufficient experience to be able to evaluate soy-protein isolate of the quality and uniformity currently being produced. The relatively poor, and particularly the varying, quality of the soy isolate made up to 2 or 3 years ago prejudiced several mills against it enough to retard its acceptance in its present improved form. As they learn of its satisfactory use by other mills, more mill men are likely to re-test soy isolate, and spend enough time to adapt their methods of its use.

[17] Only limited use of soy flour has been made for coating printing papers. Soy flour is claimed to give as good brightness or gloss as the isolate, but its use brings in a slightly greenish-yellow tinge. A solution of an impure soy-protein isolate, dissolved out of soy flour and freed from its solids by centrifuging, is being introduced for sale by tank-truck delivery to some paper coaters in Michigan, at $0.10 per pound, on a dry basis.

Whereas lack of uniform quality used to be perhaps the main disadvantage of soy isolate, its production has been improved to such an extent that many mills now consider its uniformity a prime advantage compared with most casein. Only (1) premium grade, domestic, continuous-process casein, and (2) top-grade, carefully blended, standard casein are considered its equal in uniformity. Uniformity is particularly important in producing coated paper of uniform quality without the expensive nuisance of adjusting coating formulas for different lots.

The cleanliness of soy isolate gives it a distinct advantage over most casein from Argentina, much of which is crudely made and contains a good deal of dirt, which sometimes shows up as black spots in coating.

The fact that the price of soy isolate is relatively stable, in comparison with the price of casein, is important to most users. Those interviewed mentioned the considerable fluctuation of its price from day to day and from month to month. This is particularly objectionable to mills that dislike to make speculative purchases. As casein and soy isolate become more directly interchangeable in use (pound for pound in most instances), the more stable price of soy isolate is tending toward stabilizing the price of casein. However, the price of casein is still considerably more volatile.[18]

As soy protein is used in paper coatings primarily because of its lower and more stable price, its consumption is likely to be seriously affected by any drop in prices of casein to levels which producers of soy-protein isolate cannot meet. As the costs of these producers, over and above the cost of soy meal, are much higher than those of most casein manufacturers over and above the cost of skim milk, they are vulnerable in the event of a marked drop in skim milk prices.

Apart from its uniformity and price, the main prospective advantage of soy isolate is that grades of this are being developed that permit use of higher solids-content coatings than are normally achievable with casein. A prime technical advantage of starch coatings is that their viscosity is low enough to be satisfactory and their other rheological characteristics make them suitable for coatings having a high solids content. If the solids content of protein coatings can be increased substantially, they may become suitable for use in machine coating where a high-grade, water-resistant coating is desired. Moreover, as high-solids protein coatings would be more economic for conventional off-machine coating (requiring less evaporation of moisture), proteins useful for such coatings can better resist the efforts of starch coatings to enter this market for off-machine coating.

Many disadvantages of soy isolate are cited by industrial users when its use is compared with the use of casein. Most of these are discounted by mills whose use of it is current and on a scale large

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[18] As most casein comes from Argentina, paper mills often find it desirable to place orders for it 2 to 3 months in advance. Because of its severe fluctuations in price, this is a serious disadvantage. Soy protein, as a domestically produced commodity of which reasonable inventories are maintained by manufacturers, can usually be delivered promptly after an order is received.

enough to give them the best basis for judgment, but they concede several disadvantages.

Soy isolate is still considered inferior to casein, with respect to the waterproofness of its coatings, by several mill men who are experienced in its use and who speak well of it in other respects. As lithographic and other offset printing is increasing in volume, and requires a waterproof coating for satisfactory results, this reported limitation is of increasing importance.

Diverse results obtained by different mills on the relative capability of casein and of soy-isolate coating solutions to be well waterproofed suggest that the results depend on the formulations used in different mills.

Soy isolate coatings tend to foam more than do those of the better grades of casein. This slight disadvantage is easily overcome by adding anti-foaming agents.

The brightness of the coatings made from soy-isolate is generally considered to be somewhat less satisfactory than that obtained from casein. This is commonly believed by research men to be due to the browner color of the solutions of soy isolate; however, according to reports of mills who have tested this, this color does not show up on the coated paper. Technical men in the industry believe the slightly poorer brightness and covering power of soy-protein-bound coatings may be due to a less satisfactory refractive index. This difference between the soy isolate and casein is generally regarded as too slight to be significant, and to be more than offset by the dirt in most imported casein.

The need for a higher pH solution to dissolve soy isolate than casein was claimed by one mill. It was considered disadvantageous for its effect both on the paper and on the brushes used to spread on the coating solution. This was not noted by other mills in the study.

Few of the interviewed mill men have had any experience in the last several years with paper-coating proteins other than casein and soy products. But during this period, bone glue, peanut isolate, wheat gluten, whole-corn gluten, and degraded wool waste, have been tried by some mills with varying degrees of success. The tests have been too small to give any significant clue as to the probable potential use of the products in coating processes.

Proteins vs. Other Materials

Corn starch is the main competitor of proteins in paper coating, based on its much lower net cost and higher solids content in coatings. Its suitability for use in paper coating has been tremendously increased by continuing research by its producers in cooperation with paper coaters. Modification of corn starch for paper coating has been and continues to be active, by acid and enzymic hydrolysis, by oxidation and related chemical modification, and by dextrination.[19] The modifications have been aimed at depolymerizing the starch molecules to the level suited for these adhesive applications, and altering the ratio of linear to branched polymer molecules.

[19] Substantial literature, of which a 1949 TAPPI monograph *(9)* is outstanding, notes the progress in the field, which is continuing. A recent brief review was also published in *Tappi (10)*.

The principal objectives of research on starch coating are to gain reduced viscosity and higher adhesive strength. Success in this work is mainly responsible for the great expansion in machine coating. A third objective receiving increased attention is the modification of starch, or its use with synthetic additives, to increase its water-resistance. The effect of the use of Dow 512K latex in increasing the water-resistance of starch coatings has been noted. Substantial effort has been applied to combinations of starches with products related to urea formaldehyde resins. These provide excellent water-resistance, but make too harsh a coating—one so stiff that it cracks easily when the paper is folded.

There is still some hope among researchers that starch may be used with some resinous materials which can be plasticized, to form flexible waterproof coatings.

The extent to which starches permit a higher solids content than conventional casein or soy isolate is differently reported by different mills. Probably about 60 percent solids and 40 percent water is representative for starch coatings, with one mill reporting up to 70 percent solids in special coatings. Probably about 50 percent solids and 50 percent water is representative for protein coatings, though coatings containing less than 45 percent casein were reported as the most viscous that could be used in some circumstances. Lower viscosity, alone, is not enough; the entire rheology of these protein coatings needs control. For example, the coatings tend to be too thixotropic, flowing through a pipe and nipple, but not spreading well enough on the paper.

Current prices of starches used in paper coating are about $0.05 or $0.06 a pound compared with about $0.20 a pound for proteins. The actual effective spread is less than this, however, as the proteins "go farther," than starch in binding power or adhesive value. Different mills, using varying types of coatings, estimate that 100 pounds of starch can be replaced by 48 to 67 pounds of casein; 60 pounds is the most common figure. Hence when $0.06 per pound is paid for starch, proteins have a value of $0.10 for their binding power alone. The rest of their premium goes mostly for water-resistance.

The smaller quantity of protein required to bind a unit of clay is advantageous not merely for economic reasons, but because the less binder used per unit of pigment, the better and brighter the printing surface.

A main advantage both for starches and synthetics compared with protein is that their uniformity is very high, much more so than that of most casein which many mills still consider the standard protein.

Protein coating adhesives are being squeezed on the one side by the continuing improvement of cheaper starches, and on the other by the development of synthetics. Several mills and one large supplier to the paper trade believe that it is only a question of time before proteins are pretty well squeezed out between these two. There is some expectation that synthetics will make the greater gains, and will move into some areas now held by starches.

Among the synthetics, only styrene-butadiene latex has so far won a substantial position. It, of course, is limited to use as a modifier of starch- or protein-based coatings. The hope of those who are working with other latices is that these may be able to be used more fully.

The styrene butadiene latex, Dow 512K, is used principally to provide a means for flexibilizing coatings that are made primarily from other materials. As a result, coatings using it will super-calender much better and have a better finish. Its use makes the coating more flexible, so that the paper can be creased without cracking the coating. It is claimed that it improves ink receptivity, but this is not a major factor in its use. It can be used satisfactorily up to 20 to 50 percent (depending on the end product and averaging about 30 percent) of the original weight of the other adhesives used, on a dry basis. Beyond that it tends to make the sheet too limp. On a dry basis it substitutes for protein on a pound-for-pound basis, and for starch on a basis of 1.0 pound for 1.5-2.0 pounds of starch. As it is more than twice as expensive as protein, it is used only for the best quality it can produce. It gives some waterproofness to special starch coatings, thus allowing them to be used even for cheap lithograph paper.

Wallpaper a Declining Market for Sizes

In the wallpaper industry, proteins function to bind clay and other pigment coating particles to the paper. About 90 percent of the binder, or size, used is soy protein, mostly as soy isolate, but to a lesser degree as soy flour. Starch and animal glue have been almost completely displaced by soy proteins or casein. Casein is limited to special uses; soy protein is preferred to casein in ordinary uses. Synthetic latices, particularly styrene-butadiene latex, constitute a threat to continued dominance of protein in this market. The manufacture of wallpaper is rather highly cyclical. Its increasing production in 1950 should bring it closer to capacity operations than in 1949. At capacity operation, the industry's consumption of protein binder approximates 10 million pounds per year, of which 30 percent is likely to be displaced by latex.

Manufacture of Wallpaper.—Most wallpaper is covered with a solid coat—a ground coat—and is then coated a second time with the print-design coat. Manufacture of nongrounded wallpaper, in which the design is printed directly on the paper stock, has virtually ceased. The less expensive grades of wallpaper today are not washable, but most wallpaper has been waterproofed by running it through an alum bath after the second coating or printing operation. As to quality it is classified according to design, pigments used, and the like. Usually 8 to 12 pounds of a binder are used per 100 pounds of clay. In the industry this averages about 3 pounds of binder per 100 rolls of paper. As peak annual output of the industry approximates 300 to 350 million rolls, the peak annual consumption of wallpaper size approximates 10 million pounds; during the postwar period it has averaged about 7.5 million. The manufacture of wallpaper in 1949 was reported to be at its lowest point in 25 years. It is expected by the industry to approach more nearly to normal operation during the next 5 years.

Position of Vegetable Proteins in Wallpaper Industry.—Probably 90 percent of the wallpaper coating binder now used is made of soy protein. About two-thirds of this (5 million pounds) is used as isolate and one-third as soy flour. Soy meal has been extensively tried for cheap wallpaper, but the manufacture of such wallpaper has decidedly declined. Casein is relegated to special applications, as with gold and bronze powder. One of the smaller producers continues to use animal glue, and a few producers use starch for the cheaper non-washable grades of wallpaper. The use of Dow 512K latex is increasing in blends with protein as a size; it is expected by the industry to displace one-fourth to one-third of the protein used during the next 5 years, unless demand for styrene for purposes with a higher defense priority retards this growth. Otherwise no displacement of the soy-protein coatings now used is expected within the industry. by those interviewed in the wallpaper business.

Soy isolate is generally preferred to all but the best premium-grade casein because it is now more uniform so far as pH requirements and viscosity dilution curves are concerned. Viscosity is controlled by pH regulation. Except for first-quality casein, a better brightness of color is reported for soy protein; soy protein gives more body, the paper appearing painted rather than printed. Soy flour is attractive to users because of its lower cost. The high pH required for the flour, however, causes a yellowness; to offset this with titanium dioxide or lithopone is expensive. Alternatively, a soy flour modified with wetting agents, such as low-cost petroleum sulfonates, can be used at a pH similar to that of a soy isolate.

Animal glue excels in sharpness of color, but it is not adequately washable, it congeals when temperatures drop a few degrees, and it requires more pigment. It is used for "print-coatings," in 1:2 blends with soy flour, together with a dispersing agent. This composition is claimed to provide a better, flat surface with 50 percent pigment, because of its ability to dissolve at a lower pH with a 60 percent (vs 38 percent) solids content.

Starch is limited to use with certain colored pigments; it cannot be used in conjunction with protein because the two form a curdy precipitate which cannot be handled by the pumps in modern plants. The sharpness of color obtainable with either soy protein or casein cannot be matched by starch.

Soy meal, solvent-extracted, has been used rather extensively in the past for coating cheap grades of wallpaper. A main disadvantage is that it does not "lay down" a smooth pattern.

USE OF SYNTHETIC LATICES.—Small quantities of high styrene-butadiene latex are now used in wallpaper coating, usually blended with protein to prevent curling. Increasing application of latex is anticipated by the manufacturer, ultimately displacing perhaps 30 percent of the protein used, despite the latex's higher cost. The principal supplier of latex was selling it to the wallpaper trade as a 45 percent solids emulsion for $0.26 per pound in December 1949. No other synthetic material now actively threatens; ethyl cellulose has been used on specialty wallpaper to impart grease-resistance, but is much too expensive for wide use since an organic solvent is required for its application. Likewise methyl methacrylate and vinyls have found negligible use here, although the former is applied as a water emulsion. It is doubted that such developments will account for as much as 10 percent of the wallpaper market within the foreseeable future although new materials not yet evaluated by the industry, for example, hydroxyethyl cellulose, might change this situation decidedly.

ADHESIVES.—Adhesives to make wallpaper stick to walls are based on wheat starch. Precooked and dried wheat starch is conventionally used. A wheat-protein adhesive, due to sell at about 20 cents a pound, was reported to be in a pilot-plant stage.

SUGGESTIONS FOR OILSEED RESEARCH

(1) Fundamental investigation of theories regarding paper coating would benefit the whole industry, according to the industry representatives. A basic understanding of the viscosity and other rheological characteristics of soy protein, in particular would be useful. A workably low viscosity with high solids content would be desirable for wallpaper coating. Too much water tends to carry the color into the paper, making the color less sharp and requiring more pigment; likewise it causes the paper to curl. An isolate with a higher viscosity might be preferred for the prime or ground coating as there would then be less loss of the protein into the fibers, and therefore greater adhesive strength per unit.

Methods of testing wallpaper are of an empirical nature and are inadequate for present materials. It has been shown that the traditional wax pick test for bonding strength is not applicable to latex sizes.

(2) Some method of producing an improved washable wallpaper without the use of an alum bath is highly desirable. It might possibly be achieved with a certain combination of a protein and synthetic resin binder.

INSULATING BOARD OFFERS SOME PROSPECTS FOR OILSEED PROTEINS

Insulating board, and some other wood or bagasse fiber boards, are commonly given a light pigment coating. Acoustical insulating boards are included in this group. All grades that are intended for interior use and that have an exposed surface are normally coated on this one side, by practically all firms in the industry. This coating improves the initial appearance and paintability. The natural board has a relatively rough and dark surface that is not readily paintable, and that tends to absorb oil or water paints unless previously coated.

Starches are predominantly used by the industry as the binder for these coatings. Some appreciable use is made of proteins and of synthetics in formulations analagous to those of water-based paints. The total annual *potential* market for proteins in coating these boards has been estimated as 2 to 4 million pounds; in terms of soy-protein isolate, probably only about 300,000 pounds per year are used now. This insulating-board market is expanding rather rapidly, though it is of course subject to the cyclical character of purchases of these building materials.

Starch is used because it has a lower cost and a better resistance to mold than proteins have. It has adequate water-resistance for most uses. But the industry is not fully satisfied with starch. They want a coating that is more resistant to water, fire, and roaches. Starch coatings attract roaches more than insolubilized casein or soy-isolate coatings. Starch's rather limited water-resistance is a main reason for such use of proteins as is now made—for coating board for use in which water-resistance will be particularly important. But resin emulsions (of poly-styrene and acrylic resins, for example) are considered much more of a threat to starch than are proteins.

Casein, soy-protein isolate, soy flour, and soy meal, have all been tried for coating insulating board. Only the first two are believed to be used by the industry.

In addition to the main use of starch for sizing, the industry uses it for laminating heavy stock. Most board as it comes off the machine is ½ to 1 inch thick. For greater thicknesses two boards are laminated; starch is used for this. Board so laminated meets American Standard Testing Methods, 209–48 (which requires a 2-hour soaking period) as well as the old Federal specification **LLF321B**. Soy flour is useful as a laminating adhesive, but it is not used because it is too susceptible to the growth of mold, and because it becomes infested with weevils during storage.

The following improvements are wanted in proteins to aid their use in this industry.

1. Increased water-resistance. Proteins need better means for insolubilizing them. It would greatly increase their industrial attractiveness if an insolubilizing or hardening agent could be incorporated in protein formulations (of coatings or adhesives, for example) which would insolubilize the protein without subsequent additions, but only after heating or drying.
2. Increased flexibility. Development of an effective permanent and inexpensive plasticizer for protein films is wanted.
3. Decreased susceptibility to putrefaction, mold, and mildew.
4. Simplifying of present complicated protein-dissolving method. Starches, in some forms, are simple to use.
5. Increased acid tolerance-use in neutral or acid media. Often uses of protein in paper and board are difficult or impractical because of very low alkalinity or because of acid conditions encountered.
6. Increased resistance to absorption by porous surfaces. Some starches provide such resistance. If protein is to be considered as an adhesive in plying insulating boards this increase is needed.

Paper Size a Small Market

Soy protein is now used in a product put out by a large soy-protein supplier and user. This product is reported to be prepared as a mixture of rosin and protein. The mixture as made up initially is strongly alkaline but before use it is reduced to about pH 5 which tends to precipitate the rosin from solution. The protective action of the protein prevents the rosin from coagulating, and maintains it as a dispersion. Boric acid is said to be particularly satisfactory as a means of acidifying the mixture as it acts to prevent any tendency toward flocculation.

The Institute of Paper Chemistry is reported to have used casein to stabilize wax emulsions for beater size. This size had good characteristics, especially for butchers' paper, but apparently left the paper too slippery to permit stacking it up. One company is said to have developed a protein-stabilized wax-and-rosin size that was not slippery.

None of the interviewed representatives of paper mills made any comments in which they showed much confidence concerning the value of protein stabilizers for paper sizes. This may be because their familiarity with proteins in this connection was indirect, as the proteins are incorporated by others in proprietary sizes. It was suggested that their value is enhanced in hot weather and that their use helps to keep paper within specifications limiting the amount of allowed sizing material.

WOODWORKING GLUES A LARGE MARKET

The predominant use of oilseed proteins in gluing veneers is in the softwood plywood industry, in which straight soy meal, soy-meal blends, and extended phenolic resins, are contesting the market for glues for interior-grade plywood, which accounts for the bulk of production. The trend away from straight soy meals is continuing, but large quantities are used. Soy-meal blends are enriched with more concentrated proteins—mostly blood and, to a lesser extent, casein. Although the industry expects synthetics to make further gains over the years, substantial progress in research on soy-meal glues is under way.

The smaller use of oilseed proteins in the hardwood industry, for gluing veneers, seems less likely to hold its ground for long, against its principal competitive material—extended urea resin glues—but it has been making some gains at the expense of starch.

The Softwood Plywood Industry

The softwood plywood industry in the United States consists of about 57 mills located in the Pacific Northwest. Together, they produce at capacity about 2 billion square feet of plywood per year, 95 percent of which is of Douglas fir. Nearly all of these companies buy their glues from five companies, which have branches in the area, and which are responsible for the bulk of plywood glue and gluing developments. They are depended upon for technical sales service. Three large plywood companies also produce glues but only one of them sells glues to other mills.

The industry uses soy meal (35 million pounds in 1949); soy-meal blending materials (blood, casein, and a little soy flour); phenolic resins; a little of other resins; fillers, extenders, and blending agents for these; and associated chemicals (alkalis, carbon disulfide and tetrachloride, antifoaming agents, etc.). Its use of soy meal has been declining in favor of blending agents and especially of phenolic resins; but improvements in soy products may more nearly maintain their approximate present competitive positions for the next 5 to 10 years.

Outlook for Plywood

Apart from its considerable dependence on the cyclical building industry, the main limitations on the future expansion of the production of softwood plywood appears to be the increasing scarcity and poorer quality of peeler logs (from which the veneers used for plywood production are cut), and the great expansion expected in the hardboard industry. The latter is in part a consequence of the former, as hardboard production can operate on second growth, on a sustained-yield basis. There is considerable diversity of opinion concerning the adequacy of the supplies of peeler logs; but the uncertainty is in regard to how much and how fast prices for peeler logs of good quality (by today's lowered standards) will go up, rather than whether they will increase.

Hardboard development is active among several organizations. Douglas Fir Plywood Association has developed a very light-colored hardboard. Some boards, somewhat resembling hardboard, made from resinbound (or even decayed-wood bound) waste-wood, have been developed. Most of these new hardboards and related products are expected to use synthetic resins as binders. Another related product is a plywood made of two plies of stock suitable only for cores or backs, and faced with a composition sheet made of coarse wood flour bound with phenolic resin. This overlay is about 1/16 inch thick. This is an attractive product; there is considerable current discussion within the industry about probable ultimate manufacturing costs of it. Another plywood of similar character is faced with an overlay of phenolic-impregnated paper. No instance of a trial of protein as a binder for hardboards, cores, or overlays, is known, but the plywood-glue companies are actively developing synthetic resin compositions as hardboard binders.

As a result of this increasing competition from hardboards and overlaid plywood, much of the industry expects a long-term downward trend for interior plywood, offset by an uptrend for exterior grade, emphasizing the purposes wherein waterproofness and strength count most.

The following statement from a member of the industry summarizes the viewpoint of its many well-informed men in the industry.

"The biggest long-term threat to the continued use of soy meal in plywoods is the prospect of greatly increased competition from hardboards. It appears likely that Douglas fir plywood will have a rather marked downward trend over the years in use as interior wall material. It cannot be made as cheaply as hardboards that are adequate for this important market. For present types of construction, that is, for all types of building construction except some 'prefabs' in which plywood is used as a basic structural element, plywood is much stronger than it needs to be for interior walls. With the expiration of the basic Masonite patents there has arisen a strong drive within the lumber industry, including its plywood branch, for development and production of competing hardboards."

Past Developments in the Plywood Industry

Casein had been used as the basis of plywood glues from the first World War until 1930–33. At that time, rather quickly, soy meal took over substantially the entire market for casein, on a cost basis. For a considerable period there were no standard grades of plywood, or really of plywood glues, and there were large variations in the quality of plywood, from mill to mill. Test methods were poor. All plywood was cold pressed.

The first use of resins in the production of plywood began in 1937 when cresylic resin glues were developed for use in an exterior grade plywood. Between 1938 and 1940 several plywood-glue companies began to work with phenolic glues; this resulted in the establishment of standards for exterior grades. The Douglas Fir Plywood Association then established separate standards for both exterior and interior plywood and set up a control laboratory to enforce them.[20] Interior-grade plywood was required to pass a two-cycle test of 4 hours of soaking and 20 hours of drying. The first plywood specification established by the U. S. Bureau of Standards in 1933 was CS45–33. Several subsequent revisions were made.

It was not until 1941–42 that exterior-grade plywood, other than that sold by the pioneer producer under its trade-mark, became generally recognized, accepted, and produced under controlled standards. The hot press had been introduced about 1936 or 1937, and apparently was first used with cresylic resins glues; it was used also with protein glues. In recent years protein blends and extended phenolics have been developed for interior use, and press time has been reduced. The cold press has similarly been helped by the introduction of the "no-clamp" process.

Radio-frequency-heated presses were introduced about 1940. Their use has expanded very little, although careful cost data concerning them have been compiled. Comparisons of cost data indicate that radio-frequency presses are advantageous over standard hot presses for only specialized uses or for thick panels.

During the second World War there was a large demand for an expandable type of plywood for exterior use, owing to the scarcity of facilities and materials for making standard exterior plywood. Hutment-grade plywood was developed to meet this demand. It passed a 10-cycle test, soaking 7 hours in hot water and drying 17 hours. Essentially this type has since been used as concrete-form plywood. Even from the early 1930's a better grade of glue was sold for concrete-form work and variations were made by different plywood manufacturers, each under his own brand. Finally a standard for the industry, with specifications, was evolved. The concrete-form grade, in addition to the characteristics of the Hutment grade, requires an oil dip to reduce the rate of water penetration.

In 1947 the 2-cycle test, up until then considered adequate for interior grade and still the standard for hardwood plywood, was eliminated from the Douglas Fir Plywood Association specifications. There are now again only two basic standards for adhesion, exterior grade plywood and interior, the latter meeting the 10-cycle test. Straight soy-meal glues are satisfactory for making plywood to meet the 10-cycle test, using the cold-press method; but for soy-meal glues to be used in the hot press for plywood to meet this specification, soy blends had to be developed.

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[20] The DFPA standardizes the quality and promotes the use of plywood. It serves a highly useful function. Almost the entire industry belongs. To be able to place the DFPA grade marking on plywood, one must comply with all of their quality requirements for a given grade. Their standards are more stringent than the commercial standards of the American Standards Association. For example, for exterior grade the commercial standard allows failure in 40 percent of the samples; the DFPA in only 10 percent of the samples. This is to minimize the chance of faulty goods. The DFPA also approves all new adhesive formulations except exploratory runs.

Exterior vs. Interior Plywood

Many members of the softwood plywood industry advocate that the Douglas Fir Plywood Association require that all softwood plywood meet the adhesive strength tests for exterior grade plywood, in order to avoid misuse of interior grade for purposes requiring a moisture-proof glue.[21] Such misuse tends to prejudice some users against all plywood, but those who urge this step represent a minority, and their influence seems to be declining. The consensus is that they will probably not achieve their objective within the next 10 years. Their success would eliminate the use of proteins in this industry. Should means be worked out for setting phenolic glues as quickly as protein glues, in the hot press, their case would be strengthened.

Regardless of such regulations, it is rather generally expected that the long-term outlook for exterior grade plywood, which now amounts to about one-fifth of total production, is better than the long outlook for interior grade. Its uses are developing more rapidly and it is considered less subject to competition from hardboard. But the production of exterior grade board is inflated beyond true demand during periods of peak use. As it sells at better margins, in the time of "sellers' markets" producers are likely to make it in excess of true demand, expecting that it will be bought instead of interior grade when the supply of the latter is unable to meet the demand. Thus the proportion of exterior grade produced dropped sharply from 1948 to 1949, as there was a turn from a sellers' to a buyers' market. Production in 1948, in millions of square feet, was 1,334 of interior and 620 of exterior; in 1949, interior 1,573, exterior 404.

The following quotation is representative of the arguments made by people in the plywood-glue industry who support the case for an enforced all-exterior-grade glue.

"To require the use of exterior grades exclusively for all plywood would increase the glue line costs of interior grades only from about $3 to about $4.75 per thousand square feet. To the extent that extended phenolics are now used, this increase would be due to more expensive glues (much less filler), but to the extent that soy blends are now used it would be due mostly to longer press time. The press time for exterior-grade glues is generally about the same as for extended phenolic glues—in fact, it tends to be a little less. If the industry required exterior-grade glues generally, they would still maintain interior-grade plywood, the differentiating features then being the differences in the grade of veneers used."

A large plywood producer commented: "It would cost only roughly $2 per thousand square feet of the three-ply plywood to shift from interior- to exterior-grade glues. It would cost about twice this for five-ply plywood, but this ply is much less used. At present, the price spread between interior- and exterior-grade plywood of a given type is about $6 for most grades of three-ply plywood, and about $12 for most grades of five-ply plywood, that is, almost three times the.

[21] A main reason for the drive toward a single standard of adhesives is the large potentials believed to exist for plywood in agriculture. Probably 80 percent of the potential in agriculture is for exterior grade. Plywood can be applied by farmers themselves, during their off seasons, because of its ease of installation.

difference in glue costs. The spread is greater because exterior grade tends to receive more carefully selected stock and better workmanship, and to get a better margin in price. To use exterior-grade glues exclusively would, for most grades, add little more than 2 percent to total costs." These relationships can be noted in detail in the following tabulation (table 8) of prices as of December 1949.

TABLE 8.—*Plywood, interior and exterior: Cost per thousand square feet, and spread as a percentage of interior, by ply*

	Cost per 1,000 square feet			
	Interior	Exterior	Spread	Spread as a percentage of interior
Plywood:				
⅜ inch, 3-ply:	*Dollars*	*Dollars*	*Dollars*	*Percent*
CD–CC	75	85	10	13. 3
BD–BC	88	94	6	6. 8
AD–AC	92	98	6	6. 5
AB–AB	100	106	6	6. 0
AA–AA	112	114	2	1. 78
¾ inch, 5-ply:				
CD–CC	140	150	10	7. 1
BD–BC	154	166	12	7. 8
AD–AC	158	170	12	7. 6
AB–AB	166	178	12	7. 2
AA–AA	178	186	8	4. 5

Calculated from the December 1949 price list of one of the large softwood plywood mills.

The rebuttal to these arguments is that education in proper use of interior-grade plywood, and advertising, will achieve the same objective at lower cost; that some mills would not go along in producing only exterior grade, when interior grade can be made at a lower cost and used just as well for many purposes; and that such action, making obsolete the heavy investment in cold presses and in protein adhesives, would be arbitrary and unwarranted.

COLD-PRESS VS. HOT-PRESS PRODUCTION.—Whether or not one uses straight soy glues for interior-grade plywood depends on whether he uses the cold press (or the radio-frequency press) instead of the hot press, after applying glue to the veneers and assembling them. Straight soy glues have no real competition in sight for the cold press (except possibly peanut meal) but they are not suited for hot-press work.

Hot-press production has been increasing at the expense of cold press. It is now believed to account for slightly more than half of capacity and production, and is expected to continue to increase its share, but at a much slower and a declining rate, and without reducing cold-press production to much below 20 percent, so far as can be foreseen (short of a forced shift to exterior grade, or other radical change). In cold pressing, straight soy meal is used as the base of the glue formula. In hot pressing enriched soy meal (that is, soy blends) or phenolic resins form the adhesive base. However, as cold presses are much cheaper and more quickly amortizable than hot presses, they tend to be installed by small mills in prosperous times, to "skim the cream off the boom" to a greater extent than normally, thus temporarily increasing soy meal's share. As noted below, soy blends have a shorter hot-press schedule than phenolics. In boom times, to squeeze out as much production as possible, they are used somewhat more commonly. These two factors partially offset the abnormally great use of phenolics in boom years resulting from excessive production of exterior-grade plywood.

Increased use of hot presses has had several reasons. One is the wider latitude it provides in production. Use of the hot press permits a shift between interior and exterior grades, depending on market demand and on the quality of the peeler logs at hand. Some mills which depend entirely on hot press are adding cold presses to give them greater flexibility. These additions are not so great as the hot-press additions by cold-press mills.

The hot press, with its much shorter press cycles, has provided an excellent means for greatly increasing plant capacity at low operating cost, and has been widely installed on that account. Another prime reason for growth in use of the hot press was the advancements made in hot-press production of interior-grade plywood, based on development both of soy blends and of extended phenolics that produce panels of higher quality. Until 3 or 4 years ago these advantages were great enough to cause several mills to shift to hot press exclusively. Counter-development of cold-press techniques, however, then provided an economic means for use of cold presses in making interior-grade panels meeting the D. F. P. A. 10-cycle test, and possessing qualitative advantages of their own. The "no-clamp" process at the same time permitted cutting the labor costs of the cold press with only moderate extension of its press cycle. These developments have placed the cold press in a much sounder situation.

The advantages of the cold press were summarized by one respondent company as follows: "Cold-press operations involve a lower investment, less upkeep and less drying of the veneers. Cold-pressed plywood finishes better than hot-press plywood does, especially better than exterior-grade hot press, with its high temperatures and long press time. These dry the wood and tend to cause checking. Cold-press panels are also preferred by some buyers because they tend to warp less than most hot-press panels. Although cold-press glue line costs are the same as hot, some manufacturers figure total cold-press costs per thousand square feet of plywood are less than hot press; as for cold-press work they do not have to dry the veneers down below 5 percent moisture as they do with hot press. There are also less losses on account of rejects, for there is no blistering when the cold press is used. Because of the much greater investment for a hot press ($70,000) than a cold press ($17,000), it is relatively uneconomic to produce smaller sized panels in the hot press. Because of the high overhead of the hot press, one usually needs to operate it only with full-size panels, 48 inches by 96 inches, instead of 36 inch by 84 inch panels or smaller. However, these are all relatively minor reasons that help the cold press against the trend. The 'no-clamp' process has helped cold-press operation because, though it requires a little more press time, it permits use of less labor."

Radio-frequency heating provides the speed and adaptability of hot-press operations combined with the freedom from warping of cold press, but its operation is too expensive for general use. One mill in Oregon uses a radio-frequency press, which operates on soy glues at 160 to 165° Fahrenheit. This permits use of straight soy glues; blends are not required. One can use a higher spread than would be permissible with the conventional hot press, and still avoid blistering. Radio-frequency presses are not economic for most operations, owing to the higher initial cost, and to the greater cost of the electrical power required than of the steam required in conventional hot presses. A conventional hot press is adequate for exterior-grade plywood and for kraft laminated plywood. For heavy constructions of interior-grade plywood, and for very thin veneers, the radio-frequency press offers strong quality advantages, because the moisture stays put, with no warping or checking. Another advantage is that one lays up the veneers in bundles and they are not disturbed again. This cuts the cost of labor.

Protein Blends vs. Extended Phenolics

Comparative net over-all operating costs between extended phenolics and protein blends appeared to differ slightly in the various mills visited. For the most part, however, these costs were roughly equal. It was reported that only 1 out of 10 mills keep adequate cost analyses, and these are secret. Actual data on comparative costs for all glue and gluing costs except mixing, were obtained from one mill, but such data cannot be considered representative. But for the purposes of this report, it was thought that some consideration should be given to them.

Gluing costs for this mill were lower when using protein blends than when using extended phenolics. It should be noted that this mill uses two spreaders per press (permitting full advantage to be taken of the faster press cycle of soy blends). For this and other reasons this analysis in table 9 is a little more favorable to protein blends than would be one averaging comparative costs for the entire industry.

The relative merits of protein blends and extended phenolics for use in hot-press production depend on the following factors.[22]

1. The lower cost of glue for extended phenolics.

2. Other costs of glue department—higher for extended phenolics because of their longer press time. This varies from mill to mill, depending on such factors as whether two or only one glue spreader is used per press, extent to which mill is operating its hot presses at capacity, glue costs, depending on varieties of each major type glue used, and cost-accounting systems used.

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[22] From an interview with the cost accountant and the technical production man who was most familiar with the use of glue at the large plant where actual cost data were obtained.

TABLE 9.—*Hot-press plywood gluing costs, per thousand square feet of surface, for 3/8 inch, 3-ply plywood*

Item	Gluing costs based on—							
	Press costs only				All costs except mixing			
	Soy blends		Phenolics		Soy blends		Phenolics	
	Percentage of total cost	Cost	Extended	Exterior grade	Percentage of total cost	Cost	Extended	Exterior grade
	Percent	*Dollars*	*Dollars*	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Dollars*
Materials	72	3. 07	2. 50	4. 10	44	3. 07	2. 50	4. 10
Labor and burden	28	1. 19	[1] 1. 65	[1] 1. 65	56	3. 90	[1] 5. 40	[1] 5. 40
Total	100	4. 26	4. 15	5. 75	100	6. 97	7. 90	9. 50

[1] Based on reduction of output, when using phenolics, 28 percent from the soy-blend level, due to longer press cycles required.

Calculated from cost data supplied by a principal softwood plywood producer.

3. Kind of constructions produced; soy-blend glues are not very satisfactory for heavy constructions, notably in 13/16 inch thick, five-ply plywood.

4. Uniformity in glue-handling; if mills are using phenolics for heavy construction, they may use phenolics exclusively; they do not like to bother with different glues.

5. Quality: By careful use of high-grade extended phenolics, one mill reports that it is able to make 40 percent of the output of its interior-grade plywood meet exterior-grade standards. Nevertheless, it uses only soy blends in interior-grade production, primarily to get out more production.

Despite the current use of soy blends in the industry, many of the mills expect that soy blends will gradually be displaced by phenolic-extended resins. The primary reasons for the displacement of soy blends are, (1) the desirability of using only one kind of glue in the mill, (2) the increasing relative importance of exterior-grade plywood, and (3) the expectation that, as extended phenolics are further developed, press times will be cut.

OTHER RESINS.—Only phenolic resins are used to any large extent in the softwood plywood industry. There is rarely any real staining problem here, as there is in hardwoods, with which ureas are commonly used in preference to soy meal or phenolics because of their light color. Also the generally thicker softwood veneers that are used rarely let the glues bleed through. Urea resins nevertheless are used to an extent estimated (by different sources) as between 0.8 and 1.2 million pounds annually by the industry, despite a distrust in the permanence of their strength. They are used for plywood made from Ponderosa pine (accounting for perhaps 4 percent of the industry's production) and for special fabrications in which their light color is advantageous, notably flush doors for interiors. For some other specialty constructions (white fir or cottonwood for instance), soy glues are preferred. A very little casein is used straight for a few special purposes. Resorcinol resins are limited, by their cost, to such special purposes as patching and jointing. Probably less than 75,000 pounds per year are so used, but increasing use of poorer logs will require more and more patching, hence resorcinol.

Developments Regarding Blood.—Developments regarding the use of blood in the plywood glue industry are concentrated on the possibilities for blending with phenolics, as extended phenolics in which the protein serves not only as an extender but as an auxiliary glue. By using blood as the protein, one can achieve a quicker initial set from the blood, and a strong ultimate bond from the phenolic, completed after removal from the press, because of the latent heat in the wood. This is another approach toward cutting down press time for phenolics. Blood has the advantage over oilseed meals of a high responsiveness to heat.

A leader in the development of blood in plywood glue has this to say about the outlook concerning the use of blood in soy blends and as phenolic extenders.

"Possibly most interior-grade glues will some day be displaced by blood-based glues. This would require about 500 tons per day of blood, an amount probably in excess of domestic supplies but adequately capable of supplementation by imports. However, at present, improved soy-based glues have a preferred position over the glues that are based on fertilized grade blood. This is attributed mainly to the unstable price of fertilizer grade blood, less developmental work on this grade, and not quite so good mold resistance on its part. But even at the present stage of development, blood-meal glues have several points of superiority over soy-meal glues. These are a more uniform viscosity over a larger period, a longer assembly time and superiority in cold press jobs on heavy plywood."

"Phenolics extended with blood constitute the main field of plywood-glue research on blood. The related field of the addition of a little phenolic resin to a lot of blood is also promising; the main advantage is the fungus resistance imparted by the phenolic."

Other Uses of Proteins as Phenolic Extenders.—Except for the use of blood as a phenolic extender, no other use of proteins to extend any resins is contemplated by the plywood glue industry. Of course this situation might be changed by availability of wholly new types of proteins having suitable characteristics (as, conceivably, keratin, or some radically modified oilseed protein), but there is a noteworthy lack of interest in the subject at present.

Use of proteins for extending exterior-grade plywood is of course excluded by D. F. P. A. regulations, following their experience with such use of blood.

Other Developments Regarding Protein Meal in Plywood Industry.—Oilseed protein development in the plywood glue industry has probably been retarded during recent years by the dissuasive influence of the magnitude of the effort in this field undertaken many years ago by a large company which, at one time, according to plywood glue men reporting on this attitude, had 17 research men primarily engaged on this work. Among some of those interviewed, including a few who were with that company at that time there is a belief that, by using new techniques and scientific knowledge achieved since then, and by working more fundamentally and less empirically, many of the objectives then sought would be much more likely to be reached now than the limited work during the past dozen years would indicate. Though the scale of recent and current work on oilseed proteins for glues has been much more modest, it has improved the quality.

Some of the best of this recent work is the result of close technical cooperation between a soy-meal producer and a plywood glue producer. There has been a marked increase in sales for both.

The cooperating glue producer commented that much of his company's success in research has been due to their strong cooperative program with a soy-milling company. His company believed that the only way they could make real progress was to open up their technical knowledge to the soy-meal producer, which could develop the best meals for the glue company to work with. The results of this cooperation have been mutually gratifying, and the joint work is continuing. The company has recently made a complete study of the rheology of soy-meal glues, which has been of especial help in making best use of the improved soy meals available to them.

Although conceding that the use of resins probably has greater prospects of expansion, this glue company stated that it has confidence in the future of soy meal as an adhesive for plywood production. There is room now, and always will be, they believe, for this type of adhesive in the plywood industry. Much has been published on the opposite position, but mostly by people who apparently do not know the potentialities of soy meal. In contrast, this manufacturer of plywood glue expects that if plywood production holds steady, soy glues will maintain their present volume for at least the next 5 years, though they may not maintain their percentage position, because of the industry's use of phenolics for new purposes, including not only hardboards but also plywood that is specially faced. A large part of the reason for this confidence in the future of soy meal for the intermediate term is the company's own development of substantial improvements in the quality of its soy-meal glues, reflected in substantially increased sales, and the prospect of still further improvement. The company has placed especial emphasis on protein research because resin adhesives have been subject to cut-throat competition.

There is widespread interest in tests on the influence on the quality of glue of varieties of soy beans, growing areas and conditions, harvesting and milling conditions, age, and other aspects. Some believe that fundamental work on specific characteristics to be tested for is needed; otherwise they think such tests might merely duplicate what was done many years ago.

Considerable use once was made of cottonseed and peanut meals. Linseed meal has had much more limited trial. Current interest among oilseed meals other than soy is moderate, and appears restricted to peanut meal. The large company just mentioned is reported to have prevented its licensees at one time from using soy meal unadulterated with other oilseed meals. One mill, which had tried cottonseed and peanut meals for 2 years, reported no apparent advantage, and that the cottonseed-meal glues provided poorer water resistance and higher viscosity for the same solids content.

Another glue company which used them then (1949–50), claimed to be able to duplicate the quality of straight soy meal, but with much more difficulty, because of much poorer control by the producers of these meals, who were then not technically advanced.

A third glue company said that their company has recently reinvestigated other oilseed meals, none of which equaled soy meal in their belief. They claimed that cottonseed meal has too much carbohydrates. They like the fluid and the tacky characteristics of peanut-meal glues, but not their poor moisture resistance nor the unfavorable supply situation.

A fourth glue company noted that the advantage of soy meal is due not merely to a high protein content, but also to the fact that it can be had in only very slightly denatured form. The company's tests of cottonseed meal, especially extracted to avoid denaturation, also resulted in poor glues. Similarly prepared peanut meal made an excellent glue, but was too expensive for the company's use.

An independent authority, noting the poor water resistance of cottonseed and linseed meal glues, considers peanut-meal glue distinctly promising although inferior in water resistance. He suggested the removal of carbohydrates from these meals by fermentation, to help overcome this deficiency.

The Western Regional Research Laboratory of the United States Department of Agriculture has recently initiated trial by a producer of plywood glue of keratin (calcined feathers were used in the initial tests) as a blending material to enrich soy meal for hot-press use.

Blood, and to a somewhat lesser extent casein, usually in combination, are believed principally used to enrich soy meal in hot-press blends. One glue producer uses some soy flour for this purpose, in addition to blood, and believes his company gets better net results by so doing. It has produced special soy flours experimentally to establish an optimum means for this use. Soy-protein isolate has also been tried for this purpose, but casein is preferred because, when the dry glue is mixed at the mill, use of soy-protein isolate requires more water for the same viscosity than does casein. In the hot-press operations in which these blends are used, it is important to keep the moisture content down as far as possible. Perhaps newly developed low-viscosity soy isolates may warrant a re-examination of this market.

The Bureau of the Census reports the annual use of about 5 million pounds of casein by the softwood plywood industry. There was rather general agreement among those interviewed that this was much more than is actually used, as it is used only in blends. It was considered that the census figure for most mills probably represents the estimated blood and casein content of blends, and for some mills may represent total blends used.

Two points that may be of considerable significance to the development of soy meal were established during discussions with plywood glue manufacturers on enriching soy meals for blends.

1. Soy meal appears to have some component other than its protein, possibly its hulls, which contributes to a good glue. This possibility warrants research. Its presence probably helps to account for the industry's use of soy meal instead of soy flour (a dehulled meal),

2. Yet the value of soy meal as a glue (and for practically all other

purposes) depends predominantly on its protein content. In making soy blends one adds to soy meal large quantities of other materials costing 3 to 5 times as much, to enrich this protein content. It would seem worth while for glue makers (and most other users of soy meal) to pay a premium for soy meal of exceptionally high useful protein content. For industrial users this premium might be considerably greater than would be warranted merely by applying to the increment the value of the protein content in ordinary meal. Not only would the additional percentages of meal protein probably replace expensive blood or casein, but their presence would mean less carbohydrates and other diluents, such as probably limit water resistance. It was suggested that, in order to achieve higher protein meals, the breeders of soy beans aim not merely at a higher oil content, but also at a higher percentage of protein in the residual meal.

Some comments were received during the study on such aspects as general technology in plywood gluing, formulations, quantities used per 1,000 square feet of glue line, and costs of materials. As similar data are available in the voluminous periodical and patent literature of the subject, these details are not discussed in this bulletin.

Hardwood Glues

The hardwood veneer industry uses much less of the protein adhesives than does the softwood industry. But hardwood glues are used under a much greater variety of conditions, with products ranging from the most expensive furniture veneers to cheap box-shook plywood. The industry itself includes many more plants than does the softwood plywood industry. Most of the plants are relatively small, being scattered all over the hardwood areas of the United States. The largest proportion of hardwood plywood production is in the Southeastern States, where there are 80 plywood mills, 44 of which are in the Carolinas. There are numerous mills in Wisconsin, Michigan, Indiana, New York, and Vermont. Southern mills tend to use soy-meal glues more commonly than do northern mills. Very few companies that make glue hardwood veneers have more than the most rudimentary understanding of glue technology. They are likely to depend even more than the softwood plywood industry on the technical sales service of the glue companies.

The great bulk of the glue used for hardwoods is used in gluing veneers, rather than for miscellaneous other furniture and millwork joining.

Census data on the consumption of glue in softwood plywood manufacture are available monthly. The collection of such data for the diffuse hardwood plywood industry, was discontinued at the end of World War II. At that time, the annual use of glues approximated the following, all on a dry basis:

	Million pounds
Ureas	22.0
Soy meals	10.8
Tapioca starches	7.3
Phenolics	2.9
Casein	1.5
All other [1]	10.3

[1] "All other" is believed to include other starches, other resins (melamines, resorcinols), animal glues, blood, and some extenders, but use of soy isolate in this industry, except on a trial or emergency basis, is unknown.

Reliable current estimates of the use of glue in the hardwood industry were not available from the trade associations or the glue companies, or the hardwood plywood companies. It is commonly believed that the use of urea resins is continuing to expand, at the expense of all natural materials, but that soy meal has made some counter gains at the expense of starch. This was the general observation drawn from interviews of management in hardwood mills.

On the whole, the use of soy meal has probably been declining, and may continue to decline. One well-informed glue company estimated that about 7 million pounds per year of soy meal is now used by this industry. In general, the better the technical qualifications of a plant, the more likely it is to be using resin glues.

Besides the glue companies that serve the softwood plywood industry, there are other resinous glue producers and producers of animal glue and of starches who serve the hardwood industry.

Protein Glues vs. Ureas

Two main disadvantages of protein glues compared with ureas—their main competitor in this industry—are the question of staining, and the fact that they require more water in the glue mix.

Color.—Protein glues must be applied with rather strongly alkaline solutions. In thin veneers these glues tend to bleed through porous wood structures, or they may get on the surface of the wood during the handling. Because of the free alkali present, the color of most hardwoods is affected, causing a stained appearance. This is especially true of walnut, mahogany, and oak. For example, when during a temporary shortage of urea, resins casein glues were used by a working crew who were not used to going to the trouble needed to minimize staining, the rejects went up from a very low figure to a figure that was 10 to 15 percent of the production, and these rejections were due to staining. Urea glues may bleed through, also; but with their low pH they do not stain the wood. The color of the glue line itself, as observed along its edge, is rarely important, but most woodworking plants would not want to bother with one glue for use when bleeding through is important and with another when it is not—that is, when only the edge of the glue line would show.

But if protein glues had a substantial net advantage in other respects there would be a market for them in that part of the industry in which the question of staining is not important. This is possibly one-fourth of the hardwood plywood industry, including such products as box shooks and a variety of others, like bottoms of drawers for instance. Hence, it might be worth while to explore even a dark glue, as one based on cottonseed meal, for that part of the industry, if its other characteristics were satisfactory. Some starch glues are used despite their tendency to stain and their negligible resistance to moisture.

Water Additions.—All protein glues are bucking the trend toward use of less water in glues. The ultimate objective, likely someday to be reached, is a glue that is waterless, and inherently liquid. Protein adhesives, like starches, require a lot of water and heavy spreads. This water causes the wood to expand locally, so that the bond is made while the wood is in an expanded condition. The wood needs to be dried as a result of this water addition, if it is to be sufficiently stabilized when used in furniture to avoid setting up strains there. This drying adds to the expense. Apart from this problem, since the wood becomes dried in use in any event, the glue line is then under strain. This problem is far more severe in regard to most hardwoods than in regard to softwoods, as hardwood veneers are usually much thinner, and so are more readily saturated by moisture from the glue.

One reason for keeping the water content of the glue line down is to avoid bloating during the hot press. The moisture content of the panel should be down to about 8 or 9 percent but it often is as high as 17 percent. Regardless of the extra moisture introduced with wet glues and thick glue lines, the panel should be redried, but of course no company wants to add water to the glue and then go to the expense of evaporating it out.

Limitations of Adhesives.—Basically, proteins have more of the nature of surface adhesives than is true of synthetics generally. This is the reason for the need for thick protein glue lines, for the glues are not absorbed into the wood, as are the better synthetics. Thick glue lines tend to provide poor bonds and to be less dependable and attractive. But because they are surface adhesives, they are better than resins for bonding plastic sheets to wood—for counter tops, as an instance. This represents a very small market.

Adaptability to Different Uses.—A decided advantage of ureas is the flexibility in quality that can be obtained by blending ureas with different quantities of wheat flour or other extenders, for different uses. Straight urea resins usually cost about 18 cents a pound. These are nearly all extended to varying degrees, mostly with soft-wheat flour. Straight urea does not give so good a bond as urea that has been extended with 15 to 20 percent of flour; most urea is extended with more flour than this. Straight urea resins provide a cold-water proof bond. The quantity of extender for the cheapest uses will be greater than the quantity of resin. A probable average formulation for the industry is the type 3 glue, consisting of 100 pounds each of urea resin and wheat flour, and 250 pounds of water. This is considered just barely better than casein. In general, a combination of 150 parts of flour to 100 parts of resin produces a glue considered to be about equivalent to a casein glue. Some of the better casein blends, when exceptionally well controlled, may occasionally match this. One plant that produces high-grade furniture uses 100 parts urea, 15 parts wheat flour, and 50 to 55 parts of water.

Because variations in the quantity of extender used for urea resins are so great, comparisons cannot be made of costs or of many properties, between urea and soy-meal glues, unless their composition is known. This is especially true of urea. Some mills use soy glues because they consider them cheaper than ureas; other mills claim that considerably extended ureas, of a quality equal to or better than soy-meal glues, are just as cheap. Most smaller mills, and mills that pay less for labor, probably find soy-meal glues somewhat cheaper. In many hardwood plants a main reason that soy-meal glues are used is that they require a little less care in use than do resin glues. As technical control, even of a limited sort, is extended, the use of ureas is said to expand.

Dry Bond Strength.—In general, normally extended ureas are preferred to soy protein for dry bond strength. Protein glues give adequate strength to plywood made of Douglas fir but not to hardwood plywood, because Douglas fir as a wood is weaker than hardwood. Hence, in many tests of glue, even though the glue bond for hardwood is as strong as between plies of Douglas fir, one consistently gets wood failure with Douglas fir but not with hardwood. Also, protein glues when used normally show 100 percent of wood failure in laboratory tests when used on hardwoods, but never show 100 percent wood failure under the less carefully controlled conditions of plant operation. As a practical matter, for most hardwood uses, casein provides a satisfactory dry bond; soy-protein isolate is as good. Given a substantial price advantage they would be used much more commonly.

But the strains set up by the extra water contained in the casein glue may cause increased strain throughout the entire piece of furniture, and result in bond failure. One hundred pounds of dry urea resins need about 35 pounds of water; of this wet mixture only 30 pounds is required per 1,000 square feet of single glue line. Thus about 22 pounds of resin and 8 pounds of water are used per 1,000 square feet. One hundred pounds of casein, however, needs nearly as much water, and of this wet mixture about 65 pounds, half of which is water, is required per 1,000 feet of glue line. This raises the moisture content of the wood from 4 percent to about 18 percent. For good results, this moisture has to be taken out to avoid uneven shrinkage of the plywood, which would bring strains within the panels and assemblies. It is much easier to equalize the moisture content with a thin resin glue line.

Water Resistance.—Based on practical standards, reasonably extended ureas are considered definitely to have a better wet bond strength for hardwoods than do proteins. The moisture resistance of casein and other proteins is decidedly different when used as glues in softwood as against hardwood. Protein glues are much more moisture resistant when used on Douglas fir than when used with hardwoods. Douglas fir can get the same moisture resistance with soy meal as hardwood can get with a medium-extended urea glue. For the more severe wet bond requirements, phenolics are used instead of ureas.

Results on wet bond tests, as elsewhere, depend on the degree of extension used with ureas. The net wet bond strength of most urea glues, as used, is reported to be considerably better than that of casein and other protein glues; the extent to which it is better or worse depends on how much extender is used with the urea. The urea glues show up poorly in the warm-water test called for in Federal specifications. Protein glues are not bothered by *heated* water. In the much more significant cold-water test the ureas, if not overly extended, stand up well. Actually, most hardwoods are used in conditions in which protein glues provide adequate moisture resistance.

Because, under nearly all conditions of use, wood products are exposed at times to relative humidities of 80 percent or more, there is a decided difference, over the years, in the bond of ureas and of proteins. This difference is due to the tendency of casein and other protein glues to break down, by mold or other structural destruction, when exposed to high relative humidities. There also is some question concerning the permanence of urea bonds. Some of these have now been used as much as 15 years. But their pH is still a little low and they are not yet fungus-proof. Adding 5 percent of sodium pentaphenate helps them to withstand fungal attack fairly well without affecting the bond strength. What is wanted is a cheap phenolic that handles easily.

ADAPTABILITY TO HOT-PRESS USE.—In the hardwood plywood industry soy meal can be used on the hot press as well as on the cold press. This is because this industry's test standards are less stringent than those for the softwood plywood industry, notably in requiring only a 2-cycle (not a 10-cycle) test for wet bond strength. However, urea glues tend to "set up" faster, permitting more production from this expensive equipment. Hence in the hardwood industry urea glues appear to be all but universally used in hot-press work.

As costs of labor have increased, especially in the larger or more urban mills, the hot press is commonly considered to be the more economical. One mill says that in its own experience, for thin stock of ¼ inch and under, which constitutes the bulk of operations, the hot press is twice as economical as the cold press, apart from small sizes. According to this mill, in laminating veneers to base stock, when a rather good grade of urea glue is used as the raw material (for example, one costing about $5 per 1,000 square feet), the costs of materials are about equal to the labor costs, plus overhead costs. On the hot press, overhead and labor costs are divided more or less evenly. On the cold press, the costs of labor tend to be considerably higher than overhead. For thin sections, the "lay up" and the press costs combined are cheaper when the hot press is used than are the press costs alone when the cold press is used.

A few radio-frequency presses are used, but this is so expensive that it is not generally believed that any appreciable number of installations are likely to be made in the future.

OTHER CHARACTERISTICS.—Synthetics from different sources used to be deficient in uniformity. Now the uniformity is excellent, according to testimony, giving them an advantage over proteins and starches. Shelf life of ureas used to be poor, and still is for liquid ureas, but powdered ureas, which appear to be generally preferred, maintain their character for 12 to 18 months. As phenolics have a shelf life of only 3 to 5 months at room temperature, and as production rates fluctuate violently, making inventories a problem, it is desirable to have cold-storage facilities in the plants to extend the life of the phenolics. The stable prices of synthetics are a point in their favor, but not a major one.

PROTEINS AS EXTENDERS OF UREA RESIN GLUE

Little comment was received on the possible value of proteins as urea extenders. The companies in this industry who were interviewed had had no experience with the cottonseed meal-urea compositions under development by the Southern Regional Research Laboratory. A glue company, serving mostly other markets, suggested research on urea and other ammonium compounds as liquefying agents for protein glues.

Blood has some advantages as an adhesive additive. When added to ureas it is said to extend their wet strength greatly under conditions of use for woods of high moisture content worked in hot-plate presses. In these situations, blood acts as a blocking agent to prevent starved joints, at the same time serving as an adhesive. For use on extremely dry wood, however, it is apparently as detrimental as it is helpful on moist wood; it produces in dry wood a brittle bond physically resembling that of precured resin. Blood is at best when used only in small quantities. It has very poor shelf life, its odor is highly objectionable, and, even when mixed in small quantity with ureas, it tends to support micro-organisms.

Despite the desire for wheat flours of low gluten content, as urea extenders, one chemist who works with glue did not exclude the possibility that oilseed proteins might be tailored to be as useful as blood is: "Since the effect of proteins as extenders does not appear to be well known, some reasonably basic work along this line may possibly be worth while. Conceivably some proteins may be useful as urea extenders. To be sure, the urea is a little on the acid side, but on hot-press jobs the pH is brought to about 6.0. Soy albumen might be tried as an extender for ureas and melamines, to make them a little more sensitive to heat, to cut the hot-press time. Use of proteins for this purpose may depend on fairly basic developments in which specific protein fractions, possibly given special treatments, are tailored to react in a desired fashion with the resin."

Animal Glues

Animal glues are not known to be used in the regular production of plywood but are still used by a good part of the industry for edge-gluing and miscellaneous joining. The entire industry is trending away from animal glues; the producers of the better grades have been giving them up for some time. By use of synthetics, the veneers and joints of furniture can be made so that they do not come apart when kept under conditions in which men live. Nevertheless, many furniture manufacturers in the Southeast continue to use animal glues because they are cheaper to apply than ureas.

Box Shooks

The box-shook plywood industry has standards of its own, because of the low prices at which it must sell. It has been losing ground for many years to shipping containers made of fiber; but it now appears likely, over the years, according to industry spokesmen, to gain wholly new ground. This will apparently be done by plying heavy kraft paper to veneers from hardwood that is too low in grade to serve for direct unveneered use. Orange crates and similar containers are expected to be major users. Soy-meal glues are especially useful in this kraft hardwood plying, because they adhere better than do the competitive materials to the cheap, green, wood veneers.

In the conventional production of box-shook plywood, starch is extensively used, especially on northern woods, where wet strength is not needed. But soy meal provides substantially better dry bond strength on southern woods, as gum and poplar. If the quality of the starch is satisfactory, as it is for most purposes, it is likely to be preferred, because one can use a lower spread than is needed for proteins; it is easier to use; and, as it introduces less water, no redrying is usually done on starch-bonded plywood.

Extended ureas are likely to be used only to meet certain specifications. Their net cost tends to be greater, for this grade of product.

Summary of Properties of Glues

The following summary of the properties of principal glues used by the hardwood plywood industry, as used therein, has been provided by a well-informed member of the industry.

Animal glue has good dry bond, dry shear 350–400 pounds per square inch, very little water resistance, gives no stain, is quick setting, must be heated to be used, has a clear glue line; glue is light brown; cold press is used.

Starches have good dry bond, shear 300–400 p. s. i., no water resistance, give very little stain and usually only at cracks, are slow setting, have glue lines moderately dark; glues are opaque; cold press is used.

Soybean glue has good dry bond, dry shear 350–400 p. s. i., wet shear 150–225 p. s. i., moderate water resistance; gives considerable stain, is either fast (no-clamp process) or slow setting; uses hot or cold press; has dark glue lines; glue is yellow with slight greenish tint. No soybean is used in hot press in the east.

Urea resin—high frequency has a very good dry bond, shear 400-500 p. s. i., good water resistance to cold water, moderate to hot water; gives no stain; is very quick setting; glue line is colorless to light brown, depending on quantity of flour used.

Urea resin—flour extension has very good dry bond, 400–500 p. s. i. varying downward with increasing flour extension; wet shear usually 200–300; gives no stain; sets fast with hot press; cold press gives slower setting and is catalyst controlled; glue line is colorless; glue is white.

Urea resin—no extension has dry bond, 400–800 p. s. i., wet shear 250–400 p. s. i.; gives no stain, setting fast with hot press; cold press controlled by catalyst—several hours required. Glue lines varies from light to medium brown. All liquid-urea glues have some extension; urea powders may be used on either hot or cold press without flour extension.

OTHER ADHESIVES USES—SOME MARKETS APPEAR PROMISING

The combination of water resistance and strong adhesive bond, responsible for the wide use of proteins in plywood production, also makes proteins useful in many types of adhesive products used for a great variety of other purposes.[23]

Some of these principal adhesives-using industries, and their estimated total consumption of all adhesives, have been arbitrarily classified as follows:

	Consumption of all adhesives (million pounds)
Fiberboard shipping boxes	360
Other fiber containers	15
Multiwall paper bags	30
Prepared adhesive products	20
Cork	45
Bookbinding	2

[23] The consumption of protein adhesives by the plywood industry is discussed on p. 50. Adhesives in the insulating board industry are discussed in a part of the section on paper coating (p. 40). Use of proteins in adhesives based on rubber latex is found on p. 79.

Starch shares with sodium silicate the large market for fiberboard adhesives, and it accounts for about one-third of consumption of adhesives for the uses noted above. Animal glue dominates cork binding, although egg and blood albumens are used for spotting cork to metal caps. Synthetics, such as polyvinyl acetate, threaten most of the adhesives in the remaining markets. They are already preferred in bookbinding, because of increased "mileage" (that is, spread) and for food containers, because of their nontoxic, odorless, and tasteless characteristics.

Nevertheless, the recent successful development of an adhesive based on soy protein, now used for the manufacture of solid fiberboard containers, indicates a definite possibility that vegetable proteins may be able to participate further in the large miscellaneous market for adhesives. If further modification of proteins is made possible through basic research, their unusual characteristics may frequently allow successful competition in quality with synthetics, and economic competition with starch or silicate.

Fiberboard Shipping Boxes

In this bulletin, the needs for adhesives by the paperboard- or fiberboard-container industry are discussed, first, in connection with fiberboard shipping boxes, and, second, in connection with other fiber containers. The folding and set-up box industry (rated at $663,000,000 in 1948), which accounted for 90 percent of the actual number of containers produced (about 90 billion per year in the United States), is omitted from this discussion because of its relatively negligible consumption of adhesives. (It is considered, for its use of coatings, on page 30). The production of 6.2 billion fiberboard shipping containers, in more than 300 plants, accounted for almost half the tonnage of paperboard, or 25 percent of all the production of domestic paper (of 22 million tons of paper produced in 1948, 11 million tons were paperboard). Corrugated fiberboard dominates the paperboard industry, as is evident from the following breakdown of fiberboard production (table 10).

Table 10.—*Quantity and value of fiberboard production, by kind, 1948*

Kind	Production		Value
	Square feet	Tons	
	Billion	*Million*	*Million dollars*
Corrugated	59.8	4.5	814.6
Solid	2.4	0.4	56.5
Total	62.2	4.9	871.1

Fiber Containers, August 1949, (*3, p. 146*).

(In 1949, the total production of fiberboard declined to 61.5 billion square feet, but in 1950 it was again at a very high level.)

Solid fiberboard consists of three or more paperboard liners held together by a continuous adhesive film. In corrugated board, the interior corrugated liner is necessarily adhered to the outer liners by a discontinuous adhesive bond. Solid fiberboard is heavier; it has a rather limited application in instances in which its greater strength and durability justify its higher cost. There is, in fact, a certain borderline area in the successful competition of fiberboard boxes with wood, in which the strength of solid fiberboard, without the excess bulkiness of corrugation, is preferred. Corrugated fiberboard is suitable for most applications recently dominated by wood, including even nail kegs, soft-drink containers, and containers for radios, television sets, and refrigerators.

Solid fiberboard is also used for a variety of shipping containers for products that require special protection; it is used for ammunition, for instance—and it is used for eggs. The major outlet for solid fiberboard today is for returnable beer cases. About 60 million solid fiberboard beer cases, having an average life of 25 round trips, are now manufactured annually. Moisture-resistant adhesives are needed to obtain this life.

Preference for corrugated boxes wherever physical characteristics allow becomes obvious from a comparison in cost of a corrugated and solid fiberboard box of the same size submitted by a major producer: Corrugated costs $0.13 plus $0.01 to assemble; solid costs $0.38 plus $0.05 to assemble.

Adhesives Generally Used.—Charges for the raw materials dominate the total manufacturing costs of fiberboard. Fiber content accounts for three-fourths of the cost of finished fiberboard shipping containers—adhesives represent only slightly more than 1 percent of the cost. Nevertheless, the annual sales volume of the industry, of roughly $850,000,000, represents an expenditure of about $10,000,000 for adhesives.

Probably 200 million pounds of silicate and more than 150 million pounds of starch, both computed on an anhydrous basis, were consumed by the fiberboard industry, in 1949. Starch was used almost exclusively at the inception of the corrugating industry, but was later somewhat displaced by silicate of soda, which permitted increased speeds of operation. The high solids content of sodium silicate, together with its property of increasing viscosity quickly when a little water is lost by evaporation through heat and adsorption into the fiberboard, has allowed higher rates of production. But progress in starch technology, has been helping starch to regain those markets, and its progress continues to be considerable. Characteristics of viscosity and fluidity, similar to those of the silicate, are obtained by incorporating one part of precooked starch with four parts of raw starch, and using this as a 20-percent water solution. Heat causes almost instant gelatinization to a hard gummy bond, in contrast to the formulation of the silicate bond by crystallization due principally to adsorption of water. The decided trend toward use of kraft liners, for improvement in strength, has contributed to the increasing application of starch, since the kraft liner is less easily penetrated by silicate.

Depending upon freight charges, the cost of either material ranges between $0.15 and $0.22 per thousand square feet of single-wall corrugated fiberboard. The largest domestic producer of corrugated fiberboard boxes claims that skillful handling will realize savings when starch is used. Some other manufacturers claim a smoother and faster operation if silicate is used. Silicate is sold with a varying ratio of alkali to silica, as approximately a 40-percent solution (41° Baumé). It may present a storage problem.

Adhesives Used with Solid Fiberboard.—Although many adhesives have sufficient dry bond strength to withstand the rigors that shipping containers must withstand, initial tack is the major adhesive problem in the manufacture of fiberboard. A quick-setting bond is a major criterion for use in solid fiberboard. This requirement is more severe in the production of corrugated fiberboard because of the discontinuous adhesive bond and the lack of pressure applied to solid board.

In the manufacture of solid fiberboard the liners, while traveling at a rate of 175 to 400 feet per minute, are coated with adhesive and passed through pressure rollers, and then along a distance of some 75 feet, during a period of 10 to 25 seconds, the adhesive must set sufficiently so that the fiberboard may be cut into the desired dimensions. Corrugated fiberboard, on the other hand, must be set by the time it leaves the single-facer, a period of only 1 to 2 seconds. A high solids content in the adhesive is especially desirable for solid fiberboard, as in its production dissipation of moisture is more difficult than in the manufacture of corrugated fiberboard. Likewise, as most solid fiberboard must withstand a standard 24-hour immersion test, starch (usually modified with about 10 percent of its weight of urea-formaldehyde for increased waterproofness) is preferred to silicate. Silicate bonds are rather susceptible to moisture.

Polyvinyl alcohol, which forms an insoluble film when cool but is completely soluble in water at 175° F., also proved to be an excellent moistureproof adhesive in the production of V-boxes during World War II but, despite the smaller quantities required per unit area, it is about three times as expensive as the urea-starch combination. There are some difficulties in the use of starch-urea, however, particularly a short "pot life"—that is, close pH control is required to regulate polymerization. As starch must be rather acid, tackiness is delayed and temperatures that are higher than are required with synthetics must be used to gel the adhesive properly. Therefore, except for large volume in continuous operation, use of the more expensive polyvinyl alcohol is often more feasible. Some starch-urea adhesives are used for the limited manufacture of weather-proof corrugated board.

Use of Proteins.—A major producer of solid fiberboard containers uses an adhesive for solid fiberboard based on soy-isolate, which is claimed to have technical advantages over starch-based adhesives and a probable cost advantage over such synthetics as polyvinyl alcohol. Attempts to reduce the cost by using soy meal or soy flour as extenders for soy isolate have been unsuccessful. They result in insufficient initial tack, which makes the rate of scrap prohibitive. Even more important is the tendency of the soy flour to spoil within a matter of hours, despite preservative; no spoilage problem is present with use of the isolate alone. The soy-isolate adhesive is claimed to be easy to handle and to produce a flexible, uniform adhesive film, although further improvement in initial tack would be desirable. A more uniform and a superior performance, compared with casein, is claimed.

The adhesive from soy-isolate has a serious disadvantage inherent in all proteins, however: it is difficult to obtain a high solids content while retaining a workable viscosity. Improved initial tack would probably result from an increase in solids content, but it is difficult to have solids above 40 to 45 percent with a soy-protein adhesive, although 60 to 70 percent solids are feasible with adhesives based on starch. Therefore, in addition to having a much higher initial cost than starch adhesives, the soy-protein adhesive bears an additional drying cost. With its use, it is necessary to remove almost twice as much water. Greater absorption of water from the adhesive by the liner is not feasible as it would result in warping. Development of protein isolates which can be used at substantially higher solids contents may alter this situation. As proteins are best dispersed in an alkaline medium, they are not suitable for solid fiberboard that has been internally sized for wet strength and therefore needs to be kept on the acid side of the pH scale.

Despite these disadvantages, use of soy-isolate in the adhesive formulation of a principal producer of solid fiberboard is well established. It seems likely to spread to other users. Even though it probably will not capture the entire market for adhesives used with solid fiberboard, which would approximate 4,000,000 pounds a year, it may soon obtain the bulk of this market, its users believe.

Use of soy-isolate in corrugated board is limited by its cost and its setting time, for both of which the corrugated has more stringent requirements than does the solid board. Manufacturers of some specialty water-resistant corrugated board would welcome availability of a sufficiently quick-setting protein adhesive, for purposes for which starch-urea and asphalt are inadequate.

Asphalt, incidentally, is an excellent and inexpensive water-proofing agent; but it has inferior adhesive strength and it prevents the repulping of the scrap, and this adds to the over-all manufacturing costs. Good water-vapor resistance is not obtained unless a continuous film of asphalt is present; microcrystalline waxes are not applicable to fiberboard. Some development work is being done on polyethylene, which is potentially a lower cost synthetic product than is polyvinyl alcohol. A new type of board, impregnated with molten sulfur to increase its compression resistance, retains its rigidity at high humidity; but its application will be limited by a tendency to taint foods and to corrode metals. Nevertheless, this development may allow fiberboard to obtain a part of the very large citrus-packaging business, at the expense of wood.

Resins, such as melamine, may be added to increase wet strength, but they increase the cost too much except for special purposes. Therefore, the use of asphalt, sulfur, or resins, does not remove the need for a low-cost, moisture-resistant adhesive. Further improvements, both technical and economic, will enhance the competitive position of fiberboard containers generally by making possible the manufacture of multiple carriers that will have an even longer life.

It is doubtful that the adverse factors of relatively high cost, inferior initial tack, and viscosity, can be sufficiently solved to gain any

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appreciable part in the large corrugated fiberboard industry for protein adhesives, unless they are radically improved. Expensive equipment, well adapted to the use of starch and silicate, is a major intermediate-term deterrent to the introduction of any new type of adhesive, unless it can demonstrate large economic advantages.

Suggestions for Specific Oilseed Research

Based on the suggestions made by the interviewed companies, the following recommendations for research were made:

1. Rheological studies to permit coatings with higher solids contents.

2. Reduction in the cost of isolated protein adhesives by (a) improvements in adhesive characteristics, particularly in initial tack; (b) suitable extension of soy isolate with a cruder form of oilseed protein such as soy flour (at present, soy flour even when blended in small quantities cannot be used because of its tendency to spoil); (c) development of better extenders of other types; (d) processing developments which will appreciably lower the manufacturing costs of isolating the oilseed protein.

3. Development of more fundamental knowledge on adhesiveness through the investigation of chain length, molecular degradations, methods of dispersing proteins, and especially better methods of testing bond strength. Such work could best be done on a cooperative basis, permitting application of the results of such study by processors of the proteins and major fiberboard manufacturers. In any test of adhesiveness, of course, it is necessary to specify the environment, such as temperature, pH, thickness of film, viscosity, methods of dispersion, mechanical techniques of application, and the like. Development of curves showing how both the initial and ultimate strengths of various bonds might vary under these conditions would be of considerable interest. For example, although the initial adhesive bond of soy isolate could be improved, the ultimate bond would be much higher than is necessary.

Fiberboard Coatings

If an economic means of applying colored coatings to fiberboard boxes can be developed, it will open up a large and relatively untapped advertising medium. (This application should not be confused with coating paperboard, as considered previously.) Some attention is being given to coating bulk fiberboard before its conversion into boxes, much as paperboard is coated. But in the industry, it is mostly contemplated that the fiberboard converter, or box manufacturer, would apply a special colored coating to the exterior surfaces of the fiberboard box (corrugated or solid) for special advertising purposes. Protein-containing coatings are being considered. The problems encountered in the use of proteins would be similar to those in the manufacture of water paint, although the manufacturer of fiberboard containers would probably formulate his own product.

Other Fiber Containers

Many paperboard containers, including fiber drums, paper cups, smaller convolute containers for various food products, milk containers, and shotgun shells, are grouped in this section. Broadly, starch-based adhesives dominate these various end uses, for economic reasons. Yet there is a decided trend toward adhesives based on synthetic resins where superior quality is important; frequendly, this technical superiority may result in net reductions in cost even compared with the use of starch. Neither oilseed proteins nor casein find any substantial application among these uses and there is no present reason to expect proteins to become more important here in the future.

Paper Drinking Cups.—The three major types of paper cups and their approximate participation in dollar sales, which amounted to about $65,000,000 in 1949, are: Single wrap, 40 percent; hot drink (coffee), 35 percent; and cone, 25 percent.

Single-wrap cups require an adhesive of high initial tack, as they are manufactured by bending moderately stiff paper stock around a mandrel and applying adhesive to a narrow lap joint to hold the paper in the shape of a truncated cone. Pressure is applied at the joint for about 3 seconds after which a shearing force is exerted on the adhesive bond as soon as the pressure is released. This is necessary because of the stiffness of the paper and its tendency to return to a flat position. Both the single-wrap and the cone cups can utilize starch or vinyl adhesives and, as they are treated with paraffin wax after fabrication, the water resistance of the adhesive is not of great importance. Although traditional starch, or dextrin, adhesives have demonstrated advantages in cost, there is an increasing use of vinyl adhesives, especially polyvinyl acetate, because of ease in handling and superior adhesive characteristics. The greater "mileage" of the vinyls has reduced the cost differential and some manufacturers claim over-all savings in manufacturing costs, compared with starch. There is a trend toward supplying the paper-cup manufacturers with prewaxed paper to obviate the need for applying paraffin wax after fabrication. Therefore, a water-resistant adhesive may become more important. Nevertheless, adhesives based on oilseed protein are not likely to be used because of the accepted applicability of vinyl adhesives.

Some hot-drink cups are of the single-wrap type. Starch adhesives are frequently used for these, although vinyls are preferred. Most hot drink cups, however, have been double-wrapped—that is, the paper is wrapped twice around the cup with a layer of adhesive, usually starch, between the sheets. But the conversion, by the largest supplier of hot-drink cups, to a plastic-coated single-wrap cup, points up a definite movement away from the double-wrap cup. A special synthetic adhesive is used for the plastic-coated cup.

On an anhydrous basis, about 9 million pounds of adhesives, starch, and synthetics, are consumed annually by manufacturers of cups. Almost all of them rely on adhesive suppliers whose products are discussed in more detail in the general packaging adhesive section (page 67).

Shotgun Shells.—Soy isolate is preferred by one of the two major producers of shotgun shells. Both technical and economic advantages are claimed over the traditional adhesive—starch. As the application consists in flushing two sides of a paper lining with adhesive, it is somewhat similar to the manufacture of solid fiberboard except for the extra tension caused by the spiral winding. Soy flour has enough ultimate strength, but its initial tackiness is too low.

Although reduced costs would always be desirable, the soy isolate adhesive is said to be satisfactory by the manufacturer in every way, and is claimed to be superior to casein in initial tack, in addition to being more uniform in price and quality. The waterproofness imparted by the isolate is advantageous, for otherwise high humidity will occasionally cause a shotgun shell to swell, or shells may be inadvertently damaged by being dropped into water.

Starch adhesives based on a 50-percent solids content are said to continue to be preferred by one of the two major producers, but the other applies a soy isolate adhesive of 15-percent solids content. About 100,000 pounds of soy isolate a year are currently consumed in the manufacture of shotgun shells. This use will probably not become large.

FIBER DRUMS, CANS, AND OTHER CONTAINERS.—Synthetic resins, and starch modified with synthetic resins, are gradually displacing considerable casein as an adhesive in the manufacture of other fiber containers, mostly for food use, such as fiber drums, tubes, pails, and milk containers. The manufacture of containers for frozen food constitutes a relatively small but rapidly growing industry which is utilizing vinyl hot-melt adhesives. There is some overlapping in use between the heavy-duty double-wrapped cups, and convolute wound pails, but the requirements and the current use of adhesives are similar. An all-service type of adhesive is preferred by the industry—one which, in addition to satisfactory adhesive characteristics, will be nontoxic, odorless, tasteless, and greaseproof. Vinyl-type adhesives meet such requirements satisfactorily and have exhibited better water resistance and better quality control than casein does; in addition, vinyls are often less expensive because of greater mileage. The price of a vinyl of lower molecular weight averages $0.34 per pound, and proper coating technique in conjunction with the use of a solvent recovery plant has kept costs in line with those of the traditional adhesives previously used.

Zein coatings have been of some interest because of their gloss, resistance to grease, good printability, and dispersing effect on waxes, but they have the disadvantage of inferior water resistance, tendency toward putrefaction, attractiveness to insects, and relatively high cost. Even if some of these disadvantages were overcome, the total use of zein here would probably be limited to less than 1 million pounds a year.

The rapidly growing fiber-drum business continues to use sodium silicate and some starch adhesives. Fiber drums are ordinarily used for dry materials, in powder, flake, or granulated forms, although waxes and asphalts may be poured in hot and then solidified. Liquids are beginning to be shipped in drums; the 5- and 10-gallon sizes are approved by railroads and clearance is expected on larger sizes shortly. Adhesive requirements for these special drums are best met by synthetics, however, in the opinion of their manufacturers. Polyvinyl alcohol is now preferred to casein, because of its high initial tack, although even a faster setting action would be desirable. Application of the soy-isolate adhesive used in the production of solid fiberboard may be worth trial. Current production of fiber drums at a rate of 18 million a year consumes about 1 million pounds of adhesives annually, on an anhydrous basis.

Vinyl adhesives are used exclusively for fiber milk containers the manufacture of which constitutes another growing industry. The current annual rate of production of milk containers exceeds 6 billion containers, valued roughly at $110,000,000. About 4 million pounds of the vinyl adhesive were probably used in their manufacture, in 1950. For this use proteins are limited by decided adhesive deficiencies. These deficiencies are evident in cost, taste, and pick-up; there is a possibility of bacterial growth, and the color is relatively poor. As in this use casein has been rapidly replaced by vinyls, particularly polyvinyl acetate and polyvinyl alcohol, further development work on the adhesive qualities of oilseed protein does not appear to be warranted.

MULTIWALL PAPER BAGS.—Some casein and soy isolate continue to be used as adhesives in the manufacture of multiwall paper bags. The bags are used widely and increasingly as shipping containers. Their producers consider starch modified with urea, which is considerably less expensive, to be equal and in some respects superior in quality to the proteins, despite its poor flexing strength. Small quantities of rubber latex adhesives (described on p. 77) and polyvinyl alcohol. are also consumed. Polyvinyl alcohol is used particularly for cellophane windows, as it will not penetrate through the paper, but its more general application is limited by its cost.

The most influential limitation of protein application is cost. In addition, experience with soy isolate, as well as with casein, indicates that starch and synthetic resins are much easier to work with, as the viscosity of a protein dispersion tends to change, so that in a few hours it may become too thick to apply. Lime is frequently used to enhance the waterproofness of casein; this adds further to the difficulties in processing and has a tendency to cause staining.

No figures were obtained on the consumption of adhesives in the manufacture of multiwall paper bags. But based on a well-informed estimate that about 3 percent of the weight of the bag may be considered as adhesive, the 500,000 tons of kraft paper used in the manufacture of 1.5 billion multiwall bags, in 1949, indicates a consumption of about 30 million pounds of adhesives on solids basis. Probably less than 1 million pounds of casein are included in this quantity. This consumption of casein is expected to decline further, despite an increase in the total consumption of adhesives consequent on the rapid growth of the multiwall bag industry. The feed industry alone consumes 40 to 50 percent as many containers as all the present users of multiwall bags together. Continued inroads by paper containers in the field now served by cotton and burlap bags are anticipated because of paper's marked advantage in cost.

PREPARED MISCELLANEOUS ADHESIVE PRODUCTS

The empirical use of adhesives and the inherently secret nature of the industry concerned in the manufacture of miscellaneous prepared adhesives make it a difficult field to appraise accurately. For example, one major supplier of adhesives has 10,000 adhesive formulations, with 3,000 of these comprising regular production items. More than 2,000 different raw materials are involved in these products. Development work, therefore, is limited to problems of application. Traditionally, and at present, these adhesives are largely based on starch and dextrin, but there is a strong trend toward the use of synthetic resins which now account for almost half of the market. Polyvinyl acetate is the principal synthetic used. Other synthetic latices in use include those of styrene, polyvinyl chloride, neoprene, GR–S, nitrile, and vinylidene chloride.

Casein-based adhesives continue to be used to a limited extent, although consumption of oilseed proteins by this industry is very small. Apparently no blood albumen is used. Perhaps the most important outlet for the casein adhesives is provided by the beverage industry, which requires an "ice proof" adhesive—that is, an adhesive that will hold a label on a bottle in the presence of cold water up to room temperature, despite condensation; but with which, in hot water, the label can easily be removed without leaving the scummy residue characteristic of starch-based adhesives. Synthetics have proved to be superior for most of these special adhesive applications, however, so that a continued downward trend in the prepared-adhesives industry's small use of protein-based adhesives is anticipated. Decalcomanias, another special adhesive outlet, continue to use adhesives based on starch.

Wallpaper adhesives are traditionally based on wheat, originally flour, now starch; paperhangers strongly prefer this to cornstarch. An adhesive based on wheat protein was reported to be in a pilot-plant stage, but no details are now available.

Decorative adhesives, such as are used for bathroom tile and the like, are mostly based on rosin. The fast setting time of rosin adhesives makes them useful also for speed labelling of cans, although starch adhesives generally prevail.

Technical factors are even more important than economic in limiting the use of proteins among general adhesives. The chief objection is the difficulty in solubilizing proteins, although various liquefying agents are employed to obtain a more workable viscosity. The most common of the liquefying agents is urea, although many ammonium compounds and amines, including morpholine, are used. Dicyandiamide reduces the viscosity of soy-protein dispersions up to 10 to 20 percent. But most wetting agents have negligible liquefying properties. The industry believes that development of protein application under slightly acid conditions, say in combination with urea, may warrant further work.

It is difficult to make a protein adhesive that will form a continuous film with good tack and, preferably, dry to an insoluble film. The foaming tendency of proteins can be solved satisfactorily and is not a deterrent to their use. Soy isolate is considered to have better tackiness than casein but not to form so smooth a film; neither protein has the high initial tackiness characteristic of starch. It is apparently difficult to obtain a combination of desired tackiness and workable viscosity. Synthetic resins, on the other hand, can be used easily, they exhibit better tack, and, because of the control possible, they will go much farther and so in many cases are less expensive than starch or glue.

As a rule, miscellaneous adhesives are marketed in liquid form. Consumers prefer water-soluble adhesives over the water-emulsion type, and both of these are usually much preferred to solvent-type adhesives. Use in packaging and use with labels and wallpaper are the principal outlets. The total volume of this adhesives market is roughly 20 million pounds a year, on an anhydrous basis. This is in addition, of course, to the special group of adhesive manufacturers serving the plywood industry, and operated either by different companies or by separate sections of the same company.

CORK-SPOTTING ADHESIVES.—Although such adhesives are used at a rate of only one drop per cap, the magnitude of the domestic beverage market alone makes attractive the market for adhesives for spotting, that is for sticking thin cork-liner inserts onto metal caps, especially on crown caps for carbonated beverages. About 4 million pounds per year of egg and blood albumen are now used in this work. The blood albumen (at $0.16 per pound in April 1950) has the disadvantage of unpleasant odor and low adhesive strength and is used to counterbalance the high cost of egg, which was $0.78 per pound in April 1950.

The neutral, aqueous, heat-setting special soy-protein isolate developed by the Northern Regional Research Laboratory as Gelsoy has exhibited definite advantages over albumen in preliminary tests, but results of extensive commercial testing were not yet available at the time of the survey. In addition to the fact that a somewhat lower price and lack of odor are anticipated, this isolate appears to equal egg albumen in initial tack and in quickness of setting time. The more stable viscosity of the soy product likewise makes it possible to control the quantity used more easily.

Casein does not set fast enough to spot cork to metal bottle caps satisfactorily, although it is sometimes preferred in sticking cork gaskets to plastic bottle caps—which offers a much smaller outlet. Bottle caps for whiskey are divided about evenly between plastic closures using a nitrocellulose lacquer adhesive, and cork stoppers with a wooden flange, in which synthetic materials are preferred to soy protein or albumen, as synthetics require no heat.

Cork Binders.—In fabricating corkboard used to make closures for containers for foods and other products, it is customary to incorporate a binder for the ground cork with a humectant plasticizer. The most suitable combination so far has proved to be bone glue plasticized with glycerin. It is doubtful that oilseed proteins could replace glue in this formulation even if economic considerations were disregarded, as these proteins are not now compatible with glycerin. Suitable glycols, with which oilseed proteins would be more compatible, are avoided because of their possible toxicity; the bulk of cork so fabricated is in contact with food products, particularly beverages and bottled foods. Soy flour and soy isolate have not been satisfactory so far as cork binders. Casein is also inferior to the glue used, and is more expensive.

There is an established use for several thousand pounds a month of zein in cork gaskets; the difficulty of plasticizing zein has prevented its wider usage in bottle caps but development work to this end continues. Some GR-S latex is now used as a cork binder and may replace glue to a considerable extent, according to some cork-board producers.

BOOKBINDING

Although both the adhesives and the coatings used in bookbinding offer a small potential market for vegetable proteins, there seems little likelihood that these will be able to obtain either market. About 2,000,000 pounds of adhesives and 500,000 pounds of coating are required per year.

ADHESIVES.—Despite initial higher costs of synthetic resin adhesives, their much greater covering power and ease of handling have caused a definite shift away from the traditional use of animal glue. Manufacture of inexpensive books (such as catalogues and telephone books) can be done at reduced costs by using synthetic vinyl adhesives rather than glue. The difficulty in solubilizing oilseed proteins is a major deterrent to their use, since the presence of too much water may cause warping. Bookbinding adhesives must also set instantly and have good water resistance; a certain degree of color would not be objectionable. But even if technical requirements could be met, the cost is the deciding factor. The progress made in synthetic adhesives and the savings resulting from their proper application therefore make this market an unlikely one for oilseed proteins.

COATINGS.—Standard books, as a rule, continue to have pyroxylin coatings. Glossy protective coatings are of interest for pocket books, the annual production rate of which is about 250 million; for catalogues, whose annual production is 40 million; and for children's books, of which about 35 million are manufactured annually. Most glossy covers are achieved with a spirit varnish, but many pocket books use a cellulose acetate laminate. This is not entirely satisfactory, as it tends to peel. Zein is of potential interest. The total potential market for zein, in a special varnish for this market, is roughly estimated to be 250,000 pounds a year. The cost of application, not the material, is the critical factor.

GUMMED PAPER.—Gummed paper is paper coated with a layer of adhesive and dried; when the coating is rewet it again becomes adhesive. Envelopes, stamps, and sealing tape are large users. The industry uses large quantities of adhesives, but although several producers of gummed paper have made trials of peanut and of soy isolates, and are willing to make further trials of better samples, none of the material showed enough promise to warrant a critical examination. Hence no detailed comments concerning their failings were made available to the investigators.

The stamp, envelope, and label part of the industry predominantly uses corn dextrins. Tapioca dextrins were largely used until the war cut off nearly all of the supply. The sealing-tape part of the industry predominantly uses animal glue. No interviewed sources were willing to make estimates of the extent of the use of these adhesives, or to supply data from which estimates might be made. It is believed, however, that the two largest envelope manufacturers use about 5 million pounds of dextrin annually for this purpose. Shipments of gummed paper in 1947 totaled 15,315 tons. The kinds of glues and the methods of application were so heterogeneous that it was impossible to make a comprehensive estimate of the quantity of adhesive used on gummed papers.

WATER PAINTS GOOD POTENTIAL MARKET FOR OILSEED PROTEINS

Proteins function in water paints in two ways: (1) As pigment-binding and film-forming agents in old-type powder-and-paste paints and (2) as protective colloids or stabilizers in the various so-called resin-emulsion paints (a generic term commonly used to include latex paints).

Types of Water Paints

Powder and Paste Paints.—Powder paints consist of lime, pigment, and about 10 percent casein by weight, while the paste type, made up of an alkaline solution of protein (casein or soy protein) and pigment, but no lime, uses about 1 pound of protein per gallon. Both consume a larger percentage of protein than resin-emulsion paints—these paints incorporate about 0.4 pound of protein per gallon. Although they still use more than one-third of the protein that is employed in the industry, their importance is expected to continue to decline. Hence in this report emphasis is directed toward resin-emulsion and latex paints.

There is, of course, a substantial consumption of calcimine, which is usually bound with glue (an inferior binding agent compared with casein), as well as lime- and cement-based exterior coatings, or both. Wall sizes, used on plaster before wallpaper is applied, are also usually bound with glue. Use of plastic texture paints, applied in heavy coats with a trowel or applicator, has increased, probably at the expense of calcimine, but they do not normally include proteins.

Resin-Emulsion and Latex Paints.—Resin-emulsion and latex paints are the natural development of attempts to improve the water resistance of paste paints. The excess lime produces a waterproof film with powder paints, but incorporation of resins was necessary with the more convenient paste type, to impart resistance to water. Resin-emulsion paints, therefore, include all types of paints in which the real film-forming agent is some type of alkyd resin, usually dissolved in a vegetable drying oil and mixed with water and pigment. They include protein because it is an effective dispersing agent, and not for its film-forming properties which are so important in paste and powder paints.

A high styrene-butadiene latex has recently begun to displace the alkyd-oil combination in some resin-emulsified paints, because of the improved washability and gloss of the resulting product. In addition, latex paints may be used on wet plaster or stucco without fear of the alkalinity of these surfaces hydrolyzing the natural oils or resins previously used. As proteins are the preferred stabilizer for latex paints also, this development may expand the market for water-paint stabilizers that is available to proteins. On the other hand, less protein may ultimately be used per gallon of latex paint manufactured.

Paint products based on latex are finding increasing consumer acceptance. As a result, manufacturers of water-thinned paint are becoming increasingly interested in replacing the usual alkyd drying-oil formulations with latex despite the higher cost, and despite their natural reluctance to forego their present control of raw material by depending on a chemical manufacturer for such a stabilized emulsion product.

Current annual production is believed to be at a rate of 15 million gallons. Tables 11 and 12 show the relative importance of the various types of water-thinned paints and includes estimates of casein and oilseed proteins used. The tables also show the sales of water-thinned paints from 1940 to 1947.

TABLE 11.—*Sales of water-thinned paints and contained protein, 1947*

Water-thinned paints	Quantity	Value	Estimated contained casein or oilseed proteins
Paste and semipaste form:	*Million gallons*	*Million dollars*	*Million pounds*
Resin emulsion paints:			
Interior	13.4	27.8	5.4
Exterior	.2	.4	.1
Total	13.6	28.2	5.5
Cold water paints	2.5	3.7	2.5
Powder types:	*Million pounds*	*Million dollars*	*Million pounds*
Lime and/or cement bound	38.1	3.4	0
Plastic texture, including paste	32.3	2.7	(1)
Protein bound:			
Interior	9.3	.9	.9
Exterior	3.3	.3	.3
Calcimine, hot and cold water	18.5	1.0	(1)
Other glue bound	2.6	.1	.0
Total	104.1	8.4	1.2
Total water-thinned paints	------------	40.3	9.1

[1] Small quantities may be used.

U. S. CENSUS OF MANUFACTURES, 1947 (*23*). The last column, "Estimated contained casein or oilseed proteins," is based on trade interviews.

FACTORS AFFECTING PROTEIN CONSUMPTION

CASEIN.—As casein virtually dominates in powder and paste water paints and is preferred by most producers of resin-emulsion paints, it accounts for more than half of the stabilizer market (table 13).

CORN GLUTEN.—Corn gluten has been found to exhibit equal, or perhaps even superior, performance in water paints when used alone or in conjunction with casein. It is supplied to a major manufacturer of water paints as an 80-percent crude whole-corn protein; the remainder consists of carbohydrate and some fiber. As all water paints are customarily pigmented, the color of the protein does not make much difference so long as it is lighter than dark brown or black. Soy isolate is preferred to corn gluten on a color basis but the gluten has a definite economic advantage.

CASEIN VS. SOY PROTEIN.—The preference of most manufacturers of resin-emulsified paints for casein over plant proteins, despite its slightly higher and less stable price, is due to its claimed better viscosity control and greater bonding characteristics. High viscosity allows the use of more water, thus lowering the cost, but is limited by poorer brushability. Resin-emulsion paints are thinned with water by the user. The high initial viscosity of soy isolate tends to decrease too rapidly on dilution, compared with casein, so that proper flow and brushing characteristics are difficult to control. There is apparently

TABLE 12.—*Sales of water-thinned paints, 1940–47*

Water-thinned paints	1940		1941		1942		1943	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Resin emulsion paints:	*1,000 gallons*	*1,000 dollars*	*1,000 gallons*	*1,000 dollars*	*1,000 gallons*	*1,000 dollars*	*1,000 gallons*	*1,000 dollars*
Paste and semipaste form:								
Interior	------	------	------	------	------	------	------	------
Exterior	------	------	------	------	------	------	------	------
Total	------	------	------	------	------	------	------	------
Cold water paints:								
Interior:								
Casein and other protein-bound:								
Paste and semi-paste form	3, 468	3, 637	4, 559	4, 791	4, 639	5, 272	4, 600	5, 362
	1,000 pounds	*1,000 dollars*	*1,000 pounds*	*1,000 dollars*	*1,000 pounds*	*1,000 dollars*	*1,000 pounds*	*1,000 dollars*
Dry-powder form	14, 976	1, 110	18, 363	1, 341	15, 624	1, 319	14, 413	1, 406
Glue-bound	3, 509	94	4, 049	111	3, 200	101	3, 185	119
Total	------	4, 841	------	6, 243	------	6, 692	------	6, 888
Exterior:								
Casein and other protein-bound	3, 913	241	5, 020	336	6, 181	417	4, 814	321
Lime and/or cement bound	11, 323	778	14, 184	924	9, 660	687	12, 436	901
Total	------	992	------	1, 260	------	1, 104	------	1, 223
Total cold water paints [1]	------	5, 832	------	7, 503	------	7, 796	------	8, 110
Plastic texture water paints	7, 896	561	8, 197	619	5, 879	470	5, 986	452
Calcimines:								
Hot water	29, 744	1, 180	25, 761	1, 065	15, 294	681	12, 909	571
Cold water	31, 037	1, 363	32, 878	1, 508	20, 295	1, 003	15, 583	770
Total	60, 781	2, 543	58, 639	2, 573	35, 589	1, 684	28, 492	1, 341

TABLE 12.—*Sales of water-thinned paints, 1940–47*—Continued

Water-thinned paints	1944		1945		1946		1947	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Resin emulsion paints:	*1,000 gallons*	*1,000 dollars*	*1,000 gallons*	*1,000 dollars*	*1,000 gallons*	*1,000 dollars*	*1,000 gallons*	*1,000 dollars*
Paste and semipaste form:								
Interior					16, 355	29, 623	13, 392	27, 794
Exterior					190	341	153	376
Total					16, 545	29, 964	13, 545	28, 171
Cold water paints:								
Interior:								
Casein and other protein bound:								
Paste and semipaste form	4, 338	5, 010	2, 402	3, 159	2, 530	3, 264	2, 523	3, 735
	1,000 pounds	*1,000 dollars*	*1,000 pounds*	*1,000 dollars*	*1,000 pounds*	*1,000 dollars*	*1,000 pounds*	*1,000 dollars*
Dry powder form	7, 840	680	7, 894	650	8, 828	734	9, 314	927
Glue bound	2, 698	92	2, 669	113	3, 386	146	2, 586	132
Total		5, 782		3, 922		4, 144		4, 794
Exterior:								
Casein and other protein-bound	4, 610	292	3, 900	250	3, 947	243	3, 341	266
Lime and/or cement bound	15, 099	1, 147	20, 970	1, 614	46, 065	3, 718	38, 087	3, 416
Total		1, 438		1, 864		3, 961		3, 681
Total cold water paints [1]		7, 220		5, 786		8, 104		8, 476
Plastic texture water paints	6, 620	476	9, 452	640	20, 148	1, 409	32, 326	2, 661
Calcimines:								
Hot water	11, 254	498	11, 142	497	11, 535	547	8, 626	491
Cold water	14, 553	714	14, 198	718	11, 470	522	9, 873	544
Total	25, 807	1, 212	25, 340	1, 215	23, 005	1, 069	18, 498	1, 035

[1] Includes paste and dry-powder plastic-texture water paints which cannot be shown separately without disclosing operations of individual companies.

U. S. BUREAU OF THE CENSUS, FACTS FOR INDUSTRY, Series M19H. (*24*) Series discontinued June 1948.

TABLE 13.—*Estimated consumption of protein stabilizers in water-thinned paints, 1949*

Stabilizer	Price per pound April 1950	Quantity	Stabilizer	Price per pound April 1950	Quantity
	Dollars	*Million pounds*		*Dollars*	*Million pounds*
Casein	0.21	6	Soy protein	0.19	} 2
Corn gluten	.14	2	Soy flour	.06	
			Total		10

Based on interviews with representative companies in the industry.

no relation between viscosity and dispersing action. The somewhat superior solubility characteristics of casein have also been cited as reasons for its choice, although no good comparable data have been offered. Soy protein isolate, however, has demonstrated marked technical advantages over soy flour, but the latter has found some application for economic reasons in partially replacing the isolate as a stabilizer. Application of soy isolate in water paints has been somewhat limited by patents.

PROTEINS VS. SYNTHETICS.—Proteins continue to be preferred to synthetic materials as stabilizers for resin-emulsion and latex paints primarily because of their superior dispersing action in water and their lower price. This is true despite the important disadvantages they possess. Limited application of such products as methyl cellulose (at $0.62 per pound in 1950) combined with appropriate wetting agents, such as special starches, alginates, or vegetable gums, cannot match the effect of protective colloid action of proteins on pigment particles, to provide a homogenous dispersion. Potentially, of course, synthetic emulsifiers threaten the dominant position of proteins. Shifts from resin-emulsion to latex-based paints on the use of protein stabilizers, are likely to affect the use of proteins per gallon adversely. Technological progress continually being made in regard to resin emulsions, coupled with the increasing knowledge of synthetic emulsifying agents, makes the future market of protein stabilizers a tenuous one.

PROTEIN DEFICIENCIES

Attempts to substitute other stabilizers for the proteins now in use are aided by the following serious objections to protein stabilizers. These are considered in their relative order of importance as far as water-thinned paint products are concerned.

ODOR.—The unpleasant odor of protein-based paints, due to putrefaction, has not been solved completely by use of preservatives, for though the preservatives are effective, they usually have an undesirable odor themselves.

WATER RESISTANCE.—After they are dried, surfaces coated with water paints based on protein do not have sufficient resistance to water.

In order to compete successfully with oil paints for a larger share of the market for interior paints, such surfaces must be washable, not only to facilitate cleaning, but also to gain a better initial resistance to water stains. Treatment with formaldehyde would give a satisfactory insoluble finish, but is not feasible for a packaged consumer product. Of even greater importance to future market gains is expansion into exterior protective coatings, where consumption of protein-based paints is now negligible.

PIGMENT COMPATIBILITY.—Based on covering power, one of the cheapest white pigments is the composite calcium sulfate-titanium dioxide (7:3) pigment. Unfortunately, however, the calcium precipitates out as an insoluble proteinate when mixed into a water-thinned paint based on protein. The corresponding barium composite pigment, barium sulfate-titanium dioxide, has less bulking power because of higher density. Manufacturers of water paints, therefore, must use other types of pigments, frequently less desirable, if their formulations are based on protein. Hence the manufacturers of composite calcium sulfate-titanium dioxide (7:3) have been actively promoting the use of such combinations as sulfonated castor oil and ethylene oxide fatty-acid esters as stabilizers, instead of proteins.

SPECIFIC SUGGESTIONS REGARDING OILSEED RESEARCH

As a result of this study the investigators believe the following suggested improvements are worthy and probably practicable objectives for research.

1. Investigations on which development of viscosity characteristics of low percentage (that is, 2-5 percent solids content) protein dispersions may be based. Investigating the maintenance of as constant a viscosity at these low percentages as is now possible at higher percentages.
2. Prevention of putrefaction without adversely affecting the odor.
3. Improvement of water resistance, particularly for exterior coatings. Even coatings based on synthetic latices are likely to soften under water; thus water paints continue to be confined mostly to interior application.

RELATED CONSUMING INDUSTRIES—ZEIN COATINGS

Spirit varnishes—those that dry by evaporation of a volatile solvent, usually an alcohol—have been the principal market for zein.[24] The unique alcohol solubility of zein among the vegetable proteins, which makes possible this varnish use, suggests that the discussion of these varnishes in conjunction with protein water paints. Various zein formulations, frequently blended with rosin to reduce costs, are used as gloss decorative coatings, wood sealers, and gasket cements, in competition with shellac. They also compete with Manila gum or regular nitrocellulose lacquers for overprint and label varnishes. Although zein varnishes have represented the largest single outlet for zein, they constitute a very small proportion of the varnish industry's annual sales which total $140,000,000 for varnish

[24] Latest estimates (1951) reveal that the zein fiber, Vicara, is now a larger outlet for zein than zein varnishes. Demand for zein for this purpose has probably reduced the quantity used for other purposes.

and $15,000,000 for shellac. Probably about 2 million pounds of zein have been used annually for protective coatings.

A major manufacturer of shellac, who was particularly successful in promoting a zein shellac substitute for shellac during World War II now reports an overwhelming consumer preference for shellac. Even priced at $0.50 per gallon, the zein product is rarely able to compete with shellac although probably technically as adequate for many end uses. Shellac in March 1950 was priced at $2.35 to $2.65 per gallon. Refined bone-dry shellac sold for $0.52 per pound and superfine gum shellac for $0.37 per pound, compared with a price of $0.30 per pound for zein.

An interesting rosin-zein fusion phonograph record to substitute for traditional shellac records is being developed, but is not ready to be commercialized. Sales of all phonograph records declined sharply in 1949. They are now gaining again (first half of 1950), but records of synthetic resin are accounting for a large and increasing proportion of the production. Unbreakable (all vinyl resin) and break-resistant (vinyl plus extender and filler) records accounted for 40 percent of the market, in 1949, and are expected virtually to take over the market during the next few years. In any event, the estimated production of 88 million pounds of shellac-type phonograph records, in 1949, consumed only 1 million pounds of shellac.

Grease and solvent-resistance is one of the most important characteristics of zein coatings. For example, a zein coating on the top of salt containers made of paperboard prevents penetration of the paraffin wax that is added for moisture resistance, and adds a resistance to scuff. Zein coatings do not have moisture-vapor resistance equivalent to that of the microcrystalline waxes. Zein coatings are about equal to uncoated cellophane in resistance to transmission of moisture vapor and will be improved in this respect by coating with microcrystalline wax. This lack of moisture-vapor resistance prevents application in frozen-food packages—a large and expanding market. Taste pick-up, bacterial growth, and tendency to discolor, also limit the application of zein coating in food packaging.

Zein applied from an aqueous dispersion is even more similar to protein water paints, since zein is also solubilized by means of alkalies or synthetic detergents. These coatings are limited to the same special industrial uses as zein varnishes, however, and do not have the large consumer market held by protein water paints. The choice between an aqueous or an organic solvent depends on the type of paper surface to be treated, type of coating desired, drying facilities available, and similar factors.

The industrial market for zein coatings for various applications, now rather limited, is expected to show some expansion, but total consumption of zein in this connection is not expected, during the next few years, to exceed 3 million pounds per year.

RUBBER-LATEX ADHESIVES

As a dispersing agent in rubber-latex formulation, proteins have the additional important function of enhancing adhesive qualities. Therefore, adhesives based on rubber latex (such as are used for dipping tire cords to promote better adhesion to the rubber-tire stock or for laminating metal foil, leather, paper, or cloth) usually incorporate small quantities of a protein, usually casein. Likewise, rubber dispersions used in the manufacture of dipped rubber goods customarily require protein as a stabilizer, but this outlet is relatively less important. Can-sealing compounds constitute an additional slight market. Oilseed proteins have not demonstrated properties which allow them to compete on an equal basis with casein in this market. While resorcinol-formaldehyde resin is successfully competing with casein for the large tire-cord dip market, casein continues to be preferred to synthetics for the other diverse rubber-latex formulations.

Tire-Cord Dips

Tire-cord dip formulations became essential with the advent of rayon in the manufacture of tires, for the smooth surface of rayon makes bonding with the tire stock difficult. Casein has been the preferred stabilizer for tire-cord dips because it enhances the adherence of the dip formulation to both the tire cord and the rubber stock of the tire. It also functions as a dispersing agent to prevent the flocculation of the rubber particles; and it acts as a thickening agent. About 70 percent of the tire cord now used is of rayon; nearly all of the remainder is of cotton. Cotton requires lesser quantities of dip, averaging possibly half as much. But the industry expects that, when substantially increased rayon tire capacity is completed (within the next 3 or 4 years), rayon will virtually monopolize the market. Other synthetic fibers may also find application, but the continued need of dipping the tire cord presumably will not be changed. The total requirement of stabilizer, therefore, is likely to continue to be roughly 5 million pounds per year when the production of tires is at fairly high levels. But the inherent disadvantages of protein, particularly putrefaction, have allowed resorcinol-formaldehyde resin to threaten the position of casein.

About 35 million pounds of tire-cord dip, containing about 15 percent of stabilizer, is now consumed annually. Dip formulations are made by the tire manufacturers, and compositions vary widely, depending on the type of tire, the particular source of tire cord, and the like. The tire-cord dip is particularly valued, for example, for the coarser rayon tire cord, which the industry now uses for passenger-car tires, where flex life is so important. Even the final environment of use—such as the abrasive roads of Alabama or the cold weather of Minnesota—may influence the dip formulation used.

Methods of testing prior to actual road tests, in order to evaluate the cord and the efficacy of the dip used, are a major problem of the tire industry. Constant improvement is made, especially in "dynamic" tests in the laboratory which simulate actual tire usage and which are made after the standard "static" tests to measure adhesive and cohesive characteristics under stress. Although other hydrophilic materials, such as alginates, cellulose derivatives, and vegetable gums, act as thickening agents, they do not provide the necessary adhesion to pass the rigorous tests set up as a minimum safety standard by the manufacturers of tires.

Casein vs. Oilseed Proteins.—Tests made on soy isolate indicated that the quantity required to produce an adhesion equal to that of casein resulted in too high a viscosity to be feasible. Use of low viscosity types of soy isolate under development may rectify this. Peanut isolate has given better results but is still claimed to be inferior to casein as far as bonding strength is concerned. Putrefaction is a major problem in connection with both casein and oilseed proteins, since a germicide cannot withstand the high pH (above 10) required for these. Casein is also claimed to be dispersed more easily than the oilseed proteins. Of pertinent interest to further research on oilseed proteins for tire-cord dips is the influence of the specific alkali used—soda ash, caustic soda, ammonium hydroxide, borax, etc.—on viscosity and other characteristics, even when pH and temperature are kept constant.

Resorcinol-Formaldehyde vs. Casein.—Although limited by its prevailing price in 1949 ($0.71 per pound), resorcinol resin is expected to find increasing application in tire-cord dip formulations, at the expense of casein. It has demonstrated better bonding strength and, in addition to having no problem of putrefaction, it has exhibited a water resistance that is superior to casein. This resistance is especially important with rayon tire cord, owing to its loss of tensile strength as moisture penetrates the tire. Resorcinol-formaldehyde has an advantage over other synthetic resins because its rapid cycle of condensation makes it particularly applicable to the manufacture of tires. A large tire company considers it to be twice as effective as casein; it uses resorcinol resins exclusively for tires. Another of the "big four" and several smaller manufacturers are also believed to be using resorcinol resin, although most of the rest of the trade, including two of the "big four" apparently continue to use casein. Current consumption of resorcinol resin is about 1.5 million pounds a year.

Laminating Latex Adhesives

The individual outlets for latex adhesives other than tire-cord dips (such as lamination of aluminum foil, of leather for shoe insoles, or of cloth in the textile industry) are relatively small and have been appraised only in a cursory way. Casein is used to stabilize and strengthen the bond of adhesives based on natural-rubber latex used to laminate aluminum foil; neither casein nor latex alone have sufficient bonding strength. As the demand for aluminum-foil lamination should continue to increase, a growing market for casein is expected here. The other outlets, however, where natural- as well as synthetic-rubber latices are used, represent a fairly stable market for protein stabilizers. Total consumption of casein, at present, in these adhesives is believed to be about 2 million pounds a year. The uses for these adhesives are so diverse as to hamper any development work directed specifically toward substituting oilseed proteins for casein in these uses.

Oilseed Proteins vs. Casein.—Work with soy isolate by technical men who are working with latex adhesives has indicated that it is still inferior to casein for these uses, in both adhesive strength and water resistance. Zinc oxide or formaldehyde are customarily used to improve the water resistance of casein in latex adhesives for aluminum-foil lamination.

Casein vs. Synthetic Resins.—In this field, the improved characteristics attributed to resorcinol resin are not important. Rubber-latex adhesives, stabilized with casein, are expected to continue to dominate this market. Vinyl latices are limited, because of price, to special applications.

Can-Sealing Compounds

The highly specialized formulations developed for sealing cans represent too small a market to provide any substantial potential outlet for oilseed proteins. Annual domestic production is valued at $5,000,000, whereas the total stabilizer requirements would be less than 500,000 pounds. Present formulations range from glue-glycerin combinations to mixtures of rubber, pigment, and rosin. The resistance of proteins to solvents makes them of interest for paint, varnish, and lacquer can-sealing products, but a protein gel does not have the required heat stability—for these compounds must stand up for 2 days at temperatures of 180° F.

Rubber Dispersions

Because of the scarcity of domestic casein, most casein used in rubber latices is imported from Argentina. But dispersions used for the manufacture of rubber-dipped goods, such as gloves, medical supplies and balloons, require a premium grade of casein for the best results. This so-called "high pH" casein sells for $0.28 per pound compared to the standard imported casein which sells at $0.21 per pound (March 1950). "High pH" casein has been specially processed to make it more applicable for dispersion uses. The total stabilizer market in rubber dispersions is only about 100,000 pounds annually. Little or no work has been done to adapt oilseed isolates to this use, and the small size of this highly specialized market does not appear to warrant special research effort.

PLASTICS—LIMITED POTENTIAL FOR OILSEED PROTEINS

Casein has proved to be much superior to oilseed proteins for extruded plastics. Casein (in its rennet-precipitated form) is extruded to form plastic rods, from which buttons, beads, buckles, spectacle frames, handles, novelties, and other small objects are then machined. Synthetic resins are customarily molded directly; attempts to use protein as molding powders in a way comparable to the way synthetic resins are used have not been successful. Equipment for extruding rods and cutting small objects is much less expensive than molding equipment, but costs much more to operate for long runs. But for short runs it is often more economical, in view of the cost of new dies for molding synthetics. Its use is therefore mostly limited to short runs, and to items in which its clear translucence and especially its advantages in providing variegated colors are appropriate. As many buttons (for dresses, etc.) fit one or more of these characteristics, by far the largest use of casein plastics is in connection with buttons. But the position of casein in the making of all of these items is steadily declining to the gain of synthetics.

Extruded Plastics

Estimates of the use of casein for extrusion range from 3 to 5 million pounds annually. In view of the declining trend of its use, the lower figure is probably more accurate. About 2.5 million pounds are used for buttons. The extent to which molded synthetics now dominate in the making of buttons is indicated by the following estimate of current annual consumption of plastics for this use.

Estimated current annual consumption of plastic used in the manufacture of buttons

Plastic:	Quantity (million pounds)
Urea	[1] 10.5
Casein	[2] 2.5
Others [3]	[2] 2.0
Total	15.0

[1] Estimated by Modern Plastics, February 1950 (*4*).
[2] Estimates based on trade interviews by Arthur D. Little, Inc.
[3] Includes melamine, styrene, allyl, and polyesters.

Casein vs. Synthetic Materials.—Although it is possible to obtain bright solid colors with urea resins, casein continues to be the best material for variegated colored buttons which are made by the adroit introduction of pigments during extrusion. Also casein buttons are easily dyed and the best rennet casein will make a clear translucent button. Although casein is losing more markets every year to synthetic resins, mostly ureas, it is expected to retain indefinitely much of its present share of the button market, based on its special advantages for short runs and special color effects. Extruded casein has been losing ground for its miscellaneous uses; for example, knitting needles, once predominantly of casein, are now made largely from anodized aluminum.

The pick-up of moisture exhibited by casein plastics is a marked disadvantage in connection with most plastic products, as it means dimensional instability. But it is actually advantageous in the case of casein buttons. As they are small, the dimensional instability is reduced and the moisture plasticizes them during laundering, so that they have excellent resistance to breakage during the ironing.

Because of the high water resistance of melamine buttons they are preferred by the U. S. Army for military garments, but the higher cost of the material limits its civilian use. Styrene buttons have the disadvantage of dissolving in dry-cleaning solvents and of softening under the heat of ironing.

Casein Versus Oilseed Proteins.—Attempts to replace casein extruded plastics, partially (as a casein-extender) or entirely, with soy isolate have not been commercially successful. It has been more difficult to extrude the soy isolate. Its high acid value has impeded normal dye procedures, and its darker color has limited it to dark buttons, but that in itself is a fairly large market. With the small difference in cost, there has been relatively little incentive to button manufacturers to overcome these deficiencies. More than 150,000 pounds of soy isolate has been semi-commercially extruded. Some of this work was directed toward a blend of soy isolate with a phenolic resin reacting at the former's iso-electric point. The aim was to obtain a uniform and quick cure suitable for extrusion of very large shapes, under great pressure, for industrial use. The possibilities have not been exhausted; a successful development might greatly enlarge the market. But the prospects do not appear to be bright unless soy isolate itself is modified further. Zein has found no commercial use as a plastic except as a direct shellac substitute, as in phonograph records. That use is discussed at the end of the section on water paints (page 76).

Other Applications of Molding Powder

The chief objection in this country to protein plastics is their lack of moldability, an increasingly important factor because of the high cost of labor here. Significantly, their use is considerably greater in Europe. Despite the cost of necessary equipment, the machine handling of synthetic resins makes them more feasible, economically. Therefore, there is little opportunity for oilseed proteins to find general application in the plastics industry unless they lend themselves to molding and can be sold in the same price range as the popular resins molding powders.

Economically, oilseed proteins would have to compete in this field predominantly with the following, of which the first two tend to dominate the molding-powder business. The average bulk price of these compounded molding powders in their least expensive form is as follows:

Average bulk price per pound of certain compounded molding powders [1]

Powder	Price (dollars)
Urea - formaldehyde	0.16
Phenol - formaldehyde	.17
Polystyrene	.26
Melamine - formaldehyde	.42

[1] General purpose molding compounds—i. e., filler included—as listed by Plastics World (*6*).

The structural stability and strength of phenol-formaldehyde accounts for the large consumption of this resin. But as phenolics have a flat, dull appearance, ureas are customarily used if appearance is important. Products molded from urea resins do not have the structural stability of phenolics and tend to deteriorate within about 2 years. One manufacturer stated that their prior work with protein additions to various molding compounds indicated the possibility of their imparting added luster and depth to molded products generally. But when blended with phenolic resins, the resulting decrease in strength offsets this advantage. A producer of melamine resin said he saw no reason to incorporate proteins with melamine resins.

Fillers

Oilseed proteins, in either crude or concentrated form, have not been able to compete with traditional plastic fillers on either an economic or a technical basis.

The residue from the extraction of soy isolate was used as a plastic extender for phenolic resins. This was a temporary expedient, and the material was abandoned in favor of more suitable fillers, primarily because of the poor luster in the molded plastic articles. A filler in a molded plastic product increases the strength by distributing the resin evenly, so that the optimum strength of plastic in sheet form is approximated in bulk. Wood filler, usually costing the user about \$0.04–05 per pound, about the same as soybean meal, has found extensive use, because of its porous structure; the chief objection is its adsorption of water, but this is offset by the addition of mineral filler. Special wheat flour is used as a filler particularly for laminating wood, where a 50-percent concentration cuts the glue line. Fillers are sometimes used beyond their technical optimum limits because of their low cost.

Soy flour has been tried for use as a plastic extender in the hope that it could contribute useful properties as a plastic as well as serving as a filler. It has not been satisfactory, primarily because it slows up the rate of cure of phenolic resin and increases the molding cycle. This makes the cost of soybean meal higher than the cost of wood filler although the original cost of material was approximately the same.

ASPHALT PRODUCTS—EXPANSION IN USE OF OILSEED PROTEINS NOT PROBABLE

Proteins are used in conjunction with asphalt for two diverse markets: (1) in printed felt base floor coverings, as a backing primer to prevent the asphalt from penetrating through the felt and (2) in asphalt emulsions for paving roads, where the protein aids the mixing with extraneous materials and helps to control the "setting-up" time of the emulsion.

Printed Felt Base Floor Coverings

Printed felt base floor coverings (amounting to \$90,000,000 per year in sales) dominate the resilient floor-covering market because of their relatively low price (table 14). There is no reason to anticipate a change in this market, for recent developments, such as plastic floor coverings, compete only for the more expensive part of the market.

Table 14.—*Production of smooth-surface floor covering, 1948* [1]

Material	Quantity produced		Percentage of total square yards	Average price per square foot, installed
	Square feet	Square yards		
	Million	*Million*	*Percent*	*Dollars*
Linoleum	675	75.	18. 5	0. 35
Printed felt base	2, 520	280.	69. 0	. 14
Rubber tile	58	6. 5	1. 6	. 75
Asphalt tile	400	45.	10. 9	. 30
Total	3, 653	406. 5	100. 0	

[1] Private communication in August 1949 from J. Campbell, floor-covering editor of the New York Journal of Commerce to Official Digest. February 1950, page 107.

The printed felt base floor coverings consist of a decorative wearing surface of high-gloss baked enamel on a base of asphalt-saturated felt. The sealing coat is applied as an aqueous dispersion of protein and filler to the face of asphalt-saturated felt, to prevent the asphalt from coming in contact with the enamel surface, which might cause discoloration. Although casein has been used for many years, soy products have partially replaced it, because of their lower cost and more stable price. Soy isolate is used, blended with casein, by some leading manufacturers, but others are using high-grade soy flour. For heavier coats, where it is necessary to apply hotter asphalt, straight casein is preferred because of its better stability of viscosity and slightly better coverage and sealing characteristics. These characteristics are responsible for its continued use even for lighter coatings, by some manufacturers, in blends with soy products. Probably 3 million pounds of protein are now consumed in this application, of which casein accounts for 2 million pounds, with soy isolate or flour accounting for the remainder. Introduction of a competitive material would be solely on the basis of economic advantage and apparently little else could be done to improve the competitive position of vegetable proteins in this market.

Asphalt Emulsions

Oilseed proteins now participate only in the asphalt-emulsion market and not in the larger markets for straight asphalt or asphalt cutback (that is, asphalt dissolved in petroleum distillate). In asphalt emulsions the additive stabilizes the emulsion prior to application; controls its breaking and the rate of water evaporation from the emulsion; and facilitates mixing with, and adhesion to, aggregates—such as sand, crushed stone, or cement. Casein and cottonseed meal are considered by most of the trade to be the most effective materials used for this purpose, but there is considerable competition from byproduct lignin, which is less expensive despite the larger quantities required (4 percent lignin versus 2 percent cottonseed meal). Soybean meal, flour, and isolate; blood albumen; and other proteinaceous materials, have also been used. The ratio of water in the asphalt to that in the original emulsion after 96 hours at 150° F. is the usual test for stabilizer effectiveness. In this test, for highway use, most States have minimum requirements of 0.6; casein tests about 0.85; oilseed meals test about 0.80; but the same quantity of lignin rates only about 0.3.

Asphalt-emulsion stabilizers are used in quantities averaging 1 to 2 percent of the weight of the asphalt, which comprise 60 to 70 percent of the total weight of the emulsion. The 56,000 tons of asphalt emulsion consumed in 1947 therefore probably used about 1 million pounds of stabilizer.

About 90 percent of all asphalt emulsions are applied to roads. The remaining 10 percent find industrial outlets in the building trades or as automobile undercoatings; emulsions for these uses are usually stabilized with bentonite.

As emulsions and cutbacks fall in the same price range ($0.09 to $0.10 per gallon), they can compete, particularly in cost, for road improvement wherever the heating required for straight asphalt is not feasible. Sales of both emulsion and cutback have reached a stable level; there is no present reason to anticipate the gain of one product at the expense of the other. The use of asphalt emulsions as a soil stabilizer, for underground impregnation of soil near reservoirs, or to buoy up concrete blocks in roads, does not constitute a significant outlet.

Proteins are not used in cutbacks to aid mixing these with sand or rock. Other agents are used, either fatty acid products such as ammoniated tall oil or red oil, or the more expensive cationic organic amines. There appear to be much better possibilities of expansion in the field of these additives of a non-protein type.

MISCELLANEOUS USES

Grouped in this section are various industrial applications in which oilseed proteins may possibly have an important future but because of the nature of the application the total market represented is usually now rather limited, and sometimes there is no market at all. Total consumption of casein and oilseed proteins in all these fields is probably less than 2 million pounds a year. Included in this group are the following types of products:

- Insecticide emulsifiers
- Fire foam liquids
- Printing inks
- Drug store products
- Leather finishing agents
- Printers rollers
- Sausage casings
- Photography
- Cleansing materials

Insecticide Emulsifiers

There has been a decided trend toward the agricultural use of the newer organic insecticides as emulsion sprays. An emulsifying agent is necessary to provide a homogenous mixture with water of the solvent, in which the insecticide is dissolved, as well as to impart wetting action to improve the efficacy of the spray. Synthetic-organic compounds such as fatty acid esters have virtually taken over the entire emulsifier market, however, and are also used with the alternate agricultural method of using insecticides, as wettable powders. Therefore use of casein (as calcium caseinate) as an insecticide emulsifier has been declining. The Bureau of the Census reported only 275,000 pounds of casein consumed for this use in 1944, and current use is probably much smaller.

Both wettable powders and solvent spray emulsions are popular; solvent emulsions are apparently used more and more. The various emulsifiers with trade-names, developed for use in specific solvents produced by the major petroleum companies, are largely combinations of ethylene oxide emulsifiers. They are used successfully with DDT, benzene hexachloride, chlordanes, and other organic insecticides now on the market, to stabilize a solvent solution of insecticide with water and in order to allow spraying under varying conditions. The principal suppliers of the organic emulsifiers, produce about 6 million pounds per year. Inconsiderable quantities of soy flour have been used to emulsify mineral oil for sprays.

Fire Foam Liquids

Fire foam liquids offer an outlet for a low-cost, relatively pure form of protein but, apart from abnormal wartime use, the nature of the industry limits the consumption. At present, the use of soy isolate is well established, and a slightly rising consumption may be anticipated (exclusive of any increase in military requirements).

Consumption of soy isolate for this use is now about 250,000 pounds annually. The principal threats are a development likely to result in moderately more foam per unit of protein present, and continuing work with cheaper proteins.

As cost and availability are the dominating factors, the total quantity used of hoof and horn meal, blood, and other proteins, probably slightly exceeds the soy isolate used. Soy isolate has the advantage in the matter of odor and stability; foam liquid based on hoof and horn meal is reported to have a life of only 3 to 4 years; this is enough for many governmental specifications. Both casein and zein are now too expensive for the trade; a crude corn protein has been tried and may be useful for blending, but it needs further development before it can well be used by itself. Animal glues and gelatin do not produce a sufficiently good foam to be considered; but cracklings, a residual fat byproduct from the manufacture of gelatin, may find application if a pure enough grade is available in quantity. Calcined feathers are another possible source of raw material.

A noteworthy development which would expand the market for mechanical foam would be the manufacture of a foam more resistant to alcohol and other organic solvents and therefore more adaptable to fire protection in the manufacture of organic chemicals, in which only chemical foam can now be used. The isolate of alcohol-extracted soy meal has been suggested for this purpose.

Printing Inks

The lack of hydrocarbon solubility of all oilseed proteins has limited their application in printing inks, but the unusual solubility characteristics of zein make it of considerable interest. Thus, although zein is unsuitable for rotogravure inks, it is adaptable for the clear aniline inks used for overprinting. Soy isolate has found a special use in water-emulsion inks for printing corrugated board and has proved to be more stable for this use than is casein. The total present market is only a few hundred thousand pounds a year but active development work is continuing, directed at a market for magazine ink which might use several million pounds. Zein has possibilities in three main types of inks.

1. Steam-set ink, where introduction of the proper quantity of moisture precipitates zein from a glycol solution, binding the pigment to the paper. This is used in food packaging.

2. Heat-set ink, where the same result is obtained by solvent evaporation. This is aimed at magazine printing.

3. Water-based inks, in which zein is dispersed. Use of water as the principal solvent reduces the costs. Use is directed at inexpensive wrappers and boxes.

Steam-set inks are now used commercially for printing paper food wrappers, especially bread wrappers and food cartons, because of the lack of odor, the rapid drying, and the good gloss and resistance to smudge that they exhibit. Manufacturers of food cartons are large potential consumers. The moisture present in the board is often adequate to precipitate the ink without slowing the continuous progress of the operation. But zein inks are not now suited to use on any cellophane and glassine that is likely to become wet while in use on fresh or frozen foods. Multiwall bags are also printed with this process.

It is difficult to achieve proper control when zein is used alone, for the zein is precipitated too easily, even by a high humidity. Other resins, therefore, such as maleic-treated rosins are actually the principal base, and the quantity of these resins consumed is several times the consumption of zein. The grease resistance and hardness of film imparted by the zein make it an important constituent. Formulation must be balanced between these desirable properties and operating efficiency. The problem of viscosity is believed to have been solved adequately. Glycols, particularly dipropylene glycol, are the customary solvents. The present cost of zein is believed to be the major deterrent to much wider use. Current consumption is probably a few hundred thousand pounds annually.

The continuing development work on zein inks, particularly on the heat-set type, now on a semicommercial scale, opens up the much larger market of magazine printing in which steam-set inks have not been applicable. Zein inks cost more but resist smudging and scratching better than do the conventional magazine inks. It is too early to appraise this development, but successful use of zein in this field could increase the consumption to 5 million pounds a year. A chief problem concerns the stability of pigmented zein varnishes, for impurities are present, either in the zein or in the pigment.

The possibility of achieving a chemical bond between protein-based inks and protein-coated paper has been suggested by one printing company.

Drug Store Products

The major use of casein and oilseed proteins in making products sold through drug stores is doubtless their use in dietetic products, as sources of desired amino acids. Special dietary foods for infants, for the aged, and for the sick, are principal users. Casein and other milk products are usually preferred; there is a substantial market here for an especially purified "high-nitrogen" domestic casein. A soy-protein product is supplied for persons who are allergic to milk. Casein and soy flour are used for producing some nutritional protein hydrolysates.

Slight uses of casein and oilseed proteins are made in several of other drug, cosmetic, and toiletry products. Roll-type massage creams sometimes use some casein, but a higher stearic-acid content serves the same purpose without the danger of putrefaction resulting from the casein. A little casein and zein have been used in some preparations for hair sets. There are some slight uses for egg albumen in cosmetics, but in 1941 this use totaled only 7,000 pounds.

Leather-Finishing Agents

Casein (600,000 pounds), blood albumen (estimated as 300,000–700,000 pounds), egg albumen (75,000 pounds), and shellac (relatively small) are materials used in leather finishing for which oilseed protein products might be substituted. These poundages are rough estimates. The consumption of blood albumen is now probably nearer 300,000 pounds. Casein is used for finishing both sole leather and upper leathers; the uppers use by far the most. The albumens and shellac are used on upper leather.

Although soy isolate could substitute for casein, and egg and blood-albumen, as a protein binder in leather finishing, there is neither a large potential market here for oilseed proteins nor any apparent tendency for soy isolate to replace other glazing materials. The isolate is considered somewhat more difficult to apply than casein, but this opinion is founded on rather short experience which occurred when adequate supplies of casein were not available. The conservativeness of the leather industry is evident in a reluctance to change finishing practice and use different materials unless substantial gains are readily apparent.

Although the value of the materials listed in table 15 below has almost doubled since 1939 the volume used remains approximately the same except that the use of casein has increased about 25 percent at the expense of egg albumen. The use of domestic egg albumen has fallen off appreciably because of the price of eggs, although this material is expected to be used somewhat more in the future than it is now. Imported egg albumen disappeared from any use in leather finishing many years ago. There will be a long-term increase in the demand for these finished materials as the population increases, but no radical changes in the relative use of different materials are expected.

TABLE 15.—*Materials used in finishing leather, 1939*

Material	Quantity	Value
	1,000 pounds	*1,000 dollars*
Casein	400	10
Albumen:		
Blood	700	160
Egg	140	
Synthetic resin finishes	7,000	2,050
Pigment finishes	9,000	1,700
Lacquer and shellac	2,000	400
Linseed oil	3,000	270
Prepared finishes, not included above	5,000	1,000
Solvents including naphthas and thinners	2,500	300
Dry pigments	4,700	470
Titanium dioxide	2,100	320
Gum tragacanth	40	90
Glycerine	200	50
Waxes:		
Carnauba	240	130
Beeswax and other waxes	900	175

Chemical Industries, October 1944 (*1, p. 549*).

The expansion of the leather industry is limited by the shortage of hides and by increasing competition from other materials. There has been a significant increase in the use of synthetic materials for outsoles, the largest leather outlet. In spite of the severe competition from improved synthetic polymers, the leather industry holds a unique position as a byproduct of the meat industry, in being assured of a source of its basic raw material at a price which the sale of the finished product will justify. Until skin-like structures can be synthesized, the quantity of leather produced will be limited by the quantity of meat consumed. But the materials required for finishing leather may be expected to change somewhat more than the total number of hides processed would indicate, as new qualities and decorative effects may be demanded.

CHARACTERISTICS OF FINISHING MATERIALS USED.—The decoration of leather first made use of simple aids such as vegetable dyes, egg albumen, and blood. When the supply of high-quality skins failed to equal the demands, finishers resorted to the use of pigments in place of dyes in order to cover up deficiencies in the grain quality of the leather. For several decades, therefore, the main part of leather finishing has been accomplished with casein-dispersed pigments. As yet, no competitor has appeared to challenge casein's supremacy as a combined disperser and binder of the pigments. Soy isolate has been used temporarily when supplies of casein were not adequate, but is not now used to any appreciable extent. Shellac, wax, or synthetic resins, assist in developing special features in the finish, such as gloss, flexibility, or resistance to scuff. In other words, they are additives which do not subtract from the use of casein.

In certain leather finishing (as upholstery leather) a lacquer topcoat is considered essential for weather-resistance purposes, and synthetic resins comprise a large part of the priming coats to furnish a good adherent base for the lacquers. These leathers are relatively small in volume and would not affect present considerations appreciably. The use by leather finishers of resins, waxes, shellacs, and similar additives, depends on current fashions in leather finishing and, in any event, would not greatly influence the consumption of protein binders.

For finishing upper leather, pigment and plasticizing casein-shellac formulations have been used for many years. Nitrocellulose, cellulose acetate, polyvinyl chloride, latex, urea formaldehyde, and polyacrylate dispersons, have been used for more than 10 years and, to an increasing extent in the last several years, for coating and finishing upper leathers and garment-bag and upholstery leathers.

The finishing of sole leather is an entirely different operation. It involves the application of heat and pressure under rollers, using sponge compounds, sulfonated oils, carnauba wax, casein, and ammonium hydroxide.

EGG ALBUMEN.—Egg albumen gives the highest luster in glazing and offers the fewest difficulties in operation. It is used mainly where light color in the finished product prohibits the use of blood albumen. Domestic egg albumen has a good chance of coming back into use if its price reaches a level considerably lower than it has been recently.

BLOOD ALBUMEN.—Blood albumen is generally used on the basis of lowest cost. At $0.675 per pound it sold in 1949 for about $0.05 to $0.10 less than egg albumen, which was at a low level compared with recent years. Prices of blood albumen were much steadier than those for egg albumen, the blood having sold at $0.70 during the first part of 1949 whereas the egg was more than twice that price. The leather industry now accounts for only approximately 300,000 pounds of blood albumen annually, about one-third of the total consumed in the United States.

Soy Albumen.—As far as it could be ascertained no trial of soy albumen has been made in the leather-finishing industry.

Synthetics.—Synthetic resin and related finishes are used mostly for finishing garment leathers, rather than shoe leathers. Eventually they may be a big factor, although not an exclusive one, in finishing shoe linings. They hold the advantage of being able to reduce the cost of labor through ease of application. Blood albumen, which competes with synthetic resins to some extent, must be combined with pigments, put in the glazing machine, and carried through several operations; these take considerably more labor than is required for applying synthetics. The extent to which synthetics are used depends mainly on the degree of wet scuff-resistance desired in the leather. The trend to synthetics in sheepskin, lining leathers, garments, novelties, etc., is to obtain increased resistance to wet rubbing.

Perhaps 10 percent of the nonpigment solids in the dried film of upper leathers for shoes is synthetic resins or rubber latex.

Soy Protein.—Soy isolate was mostly tried out by the leather-finishing industry as a substitute during periods when casein was scarce. At that time, the quality of both domestic and imported casein available for this use was especially poor—below the quality of soy isolate. When good casein became reasonably available again, the bulk of the industry shifted back, and so is not yet well experienced with the uniform soy isolate now available. It is generally thought that there is no fundamental reason why soy isolate could not replace casein. Although soy isolate's glazing properties generally are not considered to be quite so good as casein's, it is considered by some leather finishers to be a promising material.

Oilseed proteins probably could not replace resins, since the finish desired from the resins depends on thermo-plastics being applied under heat and pressure by rollers.

Zein.—Zein is similar to shellac in most applications. Although to a limited extent it was substituted for shellac during World War II, there is at present no large use, nor any indication of potential use for zein in this industry.

Suggested Research and Development.—Any research which is undertaken on leather-finishing materials for the industry as it now operates would best be concentrated on shoe leathers, particularly uppers, which account for the major part of leather consumed. Any real developments are expected to come from research of a more fundamental nature and will probably have to be done by organizations outside the industry.

Printers' Rollers

Experimental work on the use of oilseed proteins indicates that in anything like their present state of development they are not likely to be able to replace glue in glue-glycerine composition rollers. In 1948, 4 million pounds of glycerine were consumed to plasticize the glue being used. In general, oilseed proteins have not demonstrated enough binding strength. Zein, for example, is not tough or resilient enough, and plasticization is difficult. Casein is also unsatisfactory for it tends to case-harden to a leathery surface not sufficiently resilient for use in rollers.

Sausage Casings

Oilseed proteins do not appear to be suitable for competing with viscose in the manufacture of sausage casings. Potentially, about 10 million pounds of coating would be required for the annual production of sausage products which reaches about 2.5 billion pounds. For most sausages the viscose casing is removed after cooking, leaving a "skinless" coating of gelatin exuded from the meat within the skin, during the smoking or other processing. About 2 grams of cellulose film are required per pound of sausage. This accounts for roughly 5 percent of the value of the sausage. The possibility of peanut-protein films has been considered in the industry because of the merchandising value of peanuts as an edible product. A realization of the necessity of insolubilizing a peanut film with formaldehyde, which destroyed its edibility, brought a loss of interest. Sausage casings based on pectin seem much more feasible technically, to the industry, as they are edible and are easily removed by boiling water, but the costs are high.

Photography

Manufacturers of photographic materials and of soy isolate have been working on the possible use of oilseed isolates, among other materials, instead of the traditional and standard gelatin, in photographic emulsions, and for use elsewhere in the photographic field. Vegetable proteins have shown reasonable dispersing properties for silver halide, but they tend to give more brittle film layers than does gelatin. Setting properties, viscosity, and gel strength, are also of interest, in comparison with those of gelatin.

Approximately 7 to 8 million pounds of photographic gelatin are now being used annually in the United States, and the market is growing. As photographic gelatin is much more expensive than ordinary types, with quoted prices running about $1 per pound in 1949, apparently one could afford to apply considerable effort to produce a grade of oilseed isolate that would be especially adapted to this use. On the other hand, some of this high cost is due to the need for holding sizable inventories of separate batches of gelatin processed for this use, pending approval by the purchasers of samples subjected to exhaustive tests.

All of the major photographic companies are believed to be directing their main efforts in the displacement of gelatin to synthetics. Therefore there is the possibility, here as elsewhere, that oilseed proteins, if satisfactorily developed to meet existing requirements, may have their market cut out from under them by synthetics. However, a leading gelatin manufacturer considers a shift to synthetics still far from commercialization.

Cleansing Materials

The largest use for soy isolate, next to paper coating, is reported to have been its incorporation in a proprietary cleaning mixture. As previously formulated, this product was designed specifically for cleaning walls and other painted surfaces. It appears to have been a combination of an alkali cleaning compound and a wall size, in which the soy isolate was present for its sizing effect. This formula has since been abandoned in favor of one better suited to general-purpose cleaning—one free from the streakiness sometimes encountered with the old formulation. No soy isolate or other oilseed product is now believed to be used in any similar material.

Corn meal is reported to be used in substantial quantities as an abrasive in bar hand soaps and powdered soaps for use by mechanics. Use in such mixtures of 20 to 40 percent of soy isolate residue, treated with formaldehyde to make it nonfermentable, is reported to be patented by one of the soy-isolate producers. Similarly treated corn gluten has been suggested for the same purpose. The reason for using such materials is to provide a mildly abrasive grease-absorbing material to aid in removing grime. Representatives of two large soap companies, of whom inquiry was made, stated that protein products were not so used by their companies. Their studies of such use suggested that these products lacked attractiveness here. They were unfamiliar with the extent of such use elsewhere.

SUPPLIES

Soybeans, cottonseed, corn, and peanuts are extensively processed in the United States for oil and for protein cake. Industrial utilization of the protein cake or meal from them has been studied actively. Flaxseed is also extensively processed here, but the relatively low protein content and high gum content of its meal presents an exceptional problem.

Detailed examination of average actual protein contents of oilseed meals (used in table 16) shows that these consistently exceed the guaranteed basis used for market quotations by at least 1 to 2 percent. Table 17 on pages 94 and 95 pertains to the relative availability of the most important proteins.

Available data make it clear that sufficient protein meals are produced in this country from soy beans, cottonseed, flaxseed, and corn, to permit very large industrial protein industries to be based upon them. Peanuts are a much smaller and more expensive crop, and are mostly used directly for food, rather than as a source of oil and meals. It will probably be necessary to mechanize their methods of production, so as to reduce the costs to the levels obtaining in those parts of the world that have cheap labor, before meal from domestically produced peanuts could be depended upon for extensive industrial use.

As is evident from tables 16 and 19, a substantial quantity of peanut meal appears to be available for possible use in making the isolate. But solvent-extracted meal giving undenatured protein is greatly preferred to produce the isolate; and the preponderant part of meal is currently produced by a combination of crushing and solvent extraction which makes the meal unsuitable for this purpose.

Furthermore, adequate supplies of nuts for producing undenatured meal are reported not reliably obtainable at a satisfactory price. Since edible uses are the primary market for peanuts, a supply for industrial uses depends upon availability of surplus nuts at prices substan-

TABLE 16.—*Seeds: Estimated production, quantities processed into oil and protein meals, cake and meal, and price per pound, 1948* [1]

Crop	Produced in crop year						
	Seed	Oil and protein meal	Cake and meal	Meal			
				Percentage protein	Protein content	Price	Price protein
	Million pounds	*Million pounds*	*Million pounds*	*Percent*	*Million pounds*	*Dollars*	*Dollars*
Soybean	13, 380	11, 014	8, 656	45	3, 895	0. 038	0. 085
Cottonseed	11, 890	10, 666	4, 832	44	2, 126	. 032	. 072
Corn	204, 428	6, 153	[2] 1, 696	[2] 25	424	[2] . 027	. 110
Peanut	2, 338	315	188	45	85	. 033	. 073
Flaxseed	3, 052	2, 089	1, 338	35	468	. 034	. 098
Total	235, 088	30, 237	16, 710	------	6, 998	------	------

[1] Based on estimates made by Arthur D. Little, Inc.

[2] A combination of 23-percent protein corn-gluten feed (actual average 25 percent) and 41-percent protein-gluten meal. Prices and protein content based on 23-percent feed; therefore understates the total protein available and overstates the protein price.

Crops and Markets, 1949 (*12*). Cake and meal production and prizes from table, pp. 238–39.

Percent protein are estimated actual content. Protein content and protein price are derived figures.

tially lower than for edible uses. Government programs are intended to maintain prices to producers at levels that reflect their primary use.

The development of new breeds of oilseeds primarily emphasized the matter of increasing the oil content. Relatively little attention was directed toward increasing the percentage of protein in the residual meal after the extraction of the oil. However, increases in oil and protein content are not mutually exclusive and are urged by the trade as objectives in breeding.

There is a definite trend among processors of oilseed to turn to solvent extraction, because it gives a higher yield of oil and, incidentally, leaves a higher percentage of protein in the residual cake and meal which enhances its value for most industrial uses. The lower temperature obtainable by suitable solvent extraction, compared with the high pressures and temperatures customary with mechanical methods, gives a less denatured protein that is suitable for making the isolate needed for industrial usage.

Of the present supply of soy meal, 40 percent is now solvent extracted.[25] Solvent (extract) extraction of cottonseed has recently been

[25] Latest estimates show that more than 50 percent of soy meal is solvent extracted and the figure is expected to reach 75 percent soon (1951).

TABLE 17.—*Casein and vegetable protein isolates available for potential industrial utilization, and price per pound, 1932–50*

Year [1]	Casein [2]		Soybean protein			Peanut protein	
	Production plus imports	Price, ground, New York	Meal production	Isolate price: Calculated [3]	Isolate price: Spot [4]	Meal production	Isolated calculated price [5]
	1,000 tons	*Cents*	*1,000 tons*	*Cents*	*Cents*	*1,000 tons*	*Cents*
1932	12.8	6.3	115	3.81	--------	11	3.04
1933	16.1	11.0	84	4.97	--------	15	3.17
1934	19.4	11.8	74	6.10	--------	10	4.65
1935	20.5	12.2	220	6.24	--------	44	4.68
1936	31.2	16.1	613	5.24	--------	46	4.03
1937	36.4	14.7	496	7.43	--------	57	5.95
1938	24.5	8.6	724	5.07	--------	48	4.17
1939	28.4	12.0	1,064	4.76	--------	65	3.68
1940	35.6	12.6	1,349	5.29	14.25	30	4.89
1941	44.5	21.4	1,543	5.58	11.50	134	4.26
1942	29.6	20.6	1,845	7.66	20	57	6.77
1943	23.2	22.4	3,200	7.83	17	103	6.76
1944	31.3	24.4	3,946	9.49	19	109	8.83
1945	32.0	24.0	3,699	9.51	20	92	8.85
1946	31.9	24.0	3,837	11.41	20	80	10.18
1947	28.4	30.0	4,086	14.83	28	113	12.35
1948	27.5	34.0	3,833	16.76	20.25	107	13.87
1949	26.7	30.0	4,328	14.0	22	94	10.9
1950	-----	23.0	--------	--------	19	----	-----

demonstrated to be commercially successful but it involves several special problems. Its use is spreading. Corn-gluten feed and corn-gluten meal, obtained from the wet milling of corn in making starch, are separated mechanically in an aqueous medium which is subsequently filtered and dried. Corn-germ meal and corn-oil meal are recovered from the extraction of the oil from the corn germ by expeller alone or, usually, in combination with solvent extraction.[20] They are produced in much smaller quantities than gluten meal and, as yet, neither appears to have been utilized very much industrially for their protein content, nor to have been the subject of much experimentation to this end.

Isolation of zein doubtless starts with gluten meal, which contains about 43 percent protein; gluten feed has much bran, and only about 25 percent protein. Peanuts are not readily capable of solvent extraction; effective processes have not yet been demonstrated on a commercial scale. British plans for the production of peanut-protein isolate for fiber production are based on the use of expressed meal, despite the low yields so obtainable. Preference for expeller soy-

[20] At present (1951), two large concerns are producing corn germ by the solvent-extraction method.

TABLE 17.—*Casein and vegetable protein isolates available for potential industrial utilization, and price per pound, 1932–50*—Continued

Year [1]	Cottonseed protein		Zein		
	Meal production	Isolate calculated price [6]	Corn gluten feed production	Price	
				Calculated [7]	Spot [8]
	1,000 tons	*Cents*	*1,000 tons*	*Cents*	*Cents*
1932	2, 499	3. 40	510	5. 60	--------
1933	2, 105	4. 00	590	6. 56	--------
1934	1, 835	5. 85	577	8. 97	--------
1935	1, 588	7. 33	444	11. 73	--------
1936	1, 791	5. 93	588	10. 23	--------
1937	2, 145	8. 02	511	13. 72	--------
1938	2, 759	5. 37	545	9. 83	--------
1939	1, 970	5. 49	567	8. 17	--------
1940	1, 775	6. 83	614	9. 58	20
1941	1, 988	6. 95	759	10. 06	20
1942	1, 792	8. 87	965	12. 48	20
1943	2, 015	9. 78	927	14. 09	25
1944	1, 749	11. 83	842	17. 80	25
1945	1, 916	11. 84	864	17. 93	25
1946	1, 410	14. 66	807	21. 24	25
1947	1, 428	18. 50	1, 040	25. 35	25
1948	2, 019	20. 20	799	32. 37	25
1949	2, 416	15. 4	848	23. 2	25
1950	--------	--------	--------	--------	30

[1] For oilseed-meal production and calculated isolate prices, year beginning October of the year previous to that shown.
[2] See table on p. 112 for sources, production, and imports, separately.
[3] Based on price of 45-percent protein meal, Chicago, recovery of two-thirds of protein as isolate, not including cost of protein manufacture.
[4] At beginning of each year, alpha protein, bags, 20 tons, works; premium for 10–20 tons, ¼ cent; for under 10 tons, ½–4 cents. Source: Oil, Paint & Drug Reporter (*5*); not listed before 1940.
[5] Based on price of 45 percent protein meal, Southeastern mills, and recovery of two-thirds of protein as isolate, not including cost of protein manufacture.
[6] Based on price of 41 percent protein meal, Memphis, and recovery of ½ of protein as isolate, not including cost of protein manufacture.
[7] Based on price of 23 percent protein, Chicago, and recovery of ½ of protein as isolate, not including cost of protein manufacture.
[8] At beginning of each year, bags, 1,000 pounds, works; premium for smaller lots, 5 cents; Oil Paint & Drug Reporter (*5*). Not listed before 1940.

meal feeds, resulting in some premium for this beyond its extra oil content, has been largely overcome. It appears probable that in due course extracted cottonseed meal also will be developed, technically and by promotion, to an acceptance by feeders comparable to that of expressed meal. The movement toward solvent extraction of linseed oil from flaxseed continued to be very strong in spite of the decline in oil prices in 1949. It is expected by the trade that the premium which expeller meal commands over solvent meal will continue to decline. Even now it is insufficient to compensate for the lower recovery of oil by the expeller process.

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TABLE 18.—*Byproduct feeds: Production of cake and meal and average wholesale price per ton, bagged at leading markets, 1929–48*

Year beginning October—	Cottonseed meal		Soybean meal		Linseed meal		Peanut meal	
	Production	Price 41 percent protein Memphis	Production	Price 41 percent protein Chicago	Production	Price 34 percent protein [1] Minneapolis	Production	Price 45 percent protein Southeastern mills
	1,000 tons	*Dollars*	*1,000 tons*	*Dollars*	*1,000 tons*	*Dollars*	*1,000 tons*	*Dollars*
1929	2, 289	------	41	------	569	------	27	------
1930	2, 066	------	99	------	529	------	15	------
1931	2, 499	13. 96	115	20. 83	361	26. 10	11	18. 22
1932	2, 105	16. 40	84	27. 17	359	24. 92	15	19. 03
1933	1, 835	23. 99	74	33. 34	375	33. 39	10	27. 92
1934	1, 588	30. 07	220	34. 12	398	35. 95	44	28. 08
1935	1, 791	24. 33	613	28. 66	457	31. 04	46	24. 16
1936	2, 145	32. 88	496	40. 61	586	40. 80	57	35. 69
1937	2, 759	22. 00	724	27. 70	412	39. 70	48	25. 00
1938	1, 970	22. 50	1, 064	26. 00	481	36. 90	65	22. 05
1939	1, 775	28. 00	1, 349	28. 90	539	29. 90	30	29. 35
1940	1, 938	28. 50	1, 543	30. 50	745	29. 65	134	25. 55
1941	1, 792	36. 35	1, 845	41. 85	902	37. 55	57	40. 60
1942	2, 015	40. 10	3, 200	42. 80	798	44. 80	103	40. 55
1943	1, 749	48. 50	3, 946	51. 90	997	45. 50	109	53. 00
1944	1, 916	48. 55	3, 699	52. 00	449	45. 50	92	53. 10
1945	1, 410	60. 10	3, 837	62. 40	562	55. 55	80	61. 10
1946	1, 428	75. 85	4, 086	81. 10	374	81. 55	113	74. 10
1947	2, 019	83. 20	3, 833	91. 60	625	81. 25	107	83. 20
1948	2, 416	63. 12	4, 328	76. 39	686	67. 24	94	65. 48

In addition to these protein meals, those from other crops that are now less important to our economy are available in smaller quantities as sources of industrial proteins. The growing of sunflower, safflower, and sesame, for example, is being stimulated by the development of these oilseed crops in American agriculture. But the distinctly limited achievements to date of the industrial use of other oilseed protein products has put a low priority on the evaluation of their possibilities.

Wheat gluten is a special case. Its current supply is rather limited as it depends on the rather small market for wheat starch, of which it is a byproduct. Its limited supply and high cost tend to turn users to alternative sources. It does not appear to have unique qualities that are sufficiently attractive to warrant substantial special research.

So far it is only as feeds that these protein meals are at all important. As protein feeds they are very valuable to supplement forage and other common feedstuffs that are less rich in protein. It is their relative acceptance as feedstuffs, modified by their availability to major feed-using areas, that sets their price. This price is based primarily on their protein content, modified by its nutritional availability, freedom

TABLE 18.—*Byproduct feeds: Production of cake and meal and average wholesale price per ton, bagged at leading markets, 1929–48*—Continued

Year beginning October—	Fish meal		Gluten feed		Tankage and meat scraps	
	Production	Price 67 percent protein, San Francisco	Production	Price 23 percent protein, Chicago	Production [2]	Price digester 60 percent protein, Chicago[1]
	1,000 tons	*Dollars*	*1,000 tons*	*Dollars*	*1,000 tons*	*Dollars*
1929	121	--------	647	--------	--------	--------
1930	81	--------	541	--------	--------	--------
1931	84	--------	510	12.87	--------	27.10
1932	109	--------	590	15.10	--------	30.15
1933	157	37.12	577	20.62	--------	32.18
1934	178	29.79	444	26.98	--------	42.36
1935	200	36.21	588	23.52	--------	48.15
1936	206	44.73	511	31.57	--------	55.69
1937	176	42.59	545	22.60	608	46.00
1938	195	42.55	567	18.89	667	52.55
1939	191	51.20	614	22.05	728	49.65
1940	227	61.50	759	23.15	802	53.15
1941	184	74.60	965	28.70	835	74.25
1942	195	79.50	927	32.40	877	74.55
1943	190	79.50	842	40.95	975	74.55
1944	205	79.50	864	41.25	792	74.55
1945	188	83.45	802	48.85	745	82.80
1946	185	159.50	1,040	58.30	741	110.65
1947	189	163.20	799	74.45	822	119.40
1948	174	193.45	848	53.30	776	120.65

[1] 1937–40, 37 percent; 1944–46; 1947–48, 32 percent.
[2] Reported production is estimated to be about 95 percent of total production. Tankage as reported in the Feed Situation, 1944, 193; 1945, 155; 1946, 161; and 1947, 178 (*16*).

Production: The Feed Situation, October 1949 (*16*), except tankage and meat scraps, Agricultural Statistics, Department of Agriculture (*25*). Prices: 1931–47, Agricultural Statistics; 1948, Feed Situation (*16*). Prices presented are simple averages of monthly average prices.

from toxic components, and presence of other nutritional ingredients, such as oil. Oilseeds are commonly sold together with bran or hulls (as by corn or cottonseed processors) which have a value comparable to some hay. Often deliveries of oilseeds by farmers to processors depend upon resale to these farmers of an equivalent quantity of protein meal and hulls. Millers of oilseed commonly consider feeds to be a main part of their business; for some soybean processors it is the main part. Oilseed meals formerly were used considerably as ingredients of high-grade fertilizer. Such use is now rather limited, except for inedible products like castor pomace, because of their greater value as feeds, and the high demand for them as feeds.

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TABLE 19.—*Oilseeds: Production, disposition, imports, and season average price per pound received by farmers, 1929–49*

Year	Cottonseed			Peanuts		Soybeans [3]	
	Production	Sold to oil mills [1]	Price	Production [2]	Price	Production	Price
	Million pounds	*Million pounds*	*Cents*	*Million pounds*	*Cents*	*Million pounds*	*Cents*
1929	12, 812	9, 384	1. 55	898	3. 73	566	3. 13
1930	12, 056	8, 556	1. 10	697	3. 51	836	2. 28
1931	14, 620	9, 590	. 45	1, 056	1. 62	1, 036	. 83
1932	11, 630	7, 996	. 52	941	1. 55	909	. 90
1933	11, 022	7, 582	. 65	820	2. 85	811	1. 57
1934	8, 512	6, 422	1. 65	1, 014	3. 28	1, 389	1. 65
1935	9, 268	6, 900	1. 53	1, 153	3. 14	2, 934	1. 22
1936	10, 944	8, 430	1. 67	1, 260	3. 72	2, 023	2. 12
1937	15, 688	11, 926	. 98	1, 233	3. 30	2, 770	1. 42
1938	9, 900	7, 630	1. 09	1, 289	3. 27	3, 714	1. 12
1939	9, 738	7, 274	1. 06	1, 213	3. 40	5, 408	1. 35
1940	10, 572	7, 996	1. 09	1, 766	3. 33	4, 683	1. 50
1941	9, 106	7, 496	2. 38	1, 475	4. 66	6, 432	2. 58
1942	10, 404	8, 302	2. 28	2, 193	6. 08	11, 251	2. 68
1943	9, 376	7, 106	2. 61	2, 176	7. 12	11, 408	3. 02
1944	9, 804	8, 128	2. 64	2, 081	8. 04	11, 517	3. 42
1945	7, 328	5, 688	2. 56	2, 042	8. 27	11, 524	3. 47
1946	7, 026	5, 708	3. 60	2, 038	9. 10	12, 077	4. 28
1947	9, 302	7, 860	4. 30	2, 183	10. 10	11, 013	5. 57
1948	12, 072	10, 420	[7] 3. 89	2, 268	[7] 10. 50	13, 212	[7] 3. 98
1949	[9] 12, 054			[9] 1, 800		[9] 12, 252	

Nearly all oilseed meals are used as feedstuffs. The market outlook for this use is generally considered to be exceptionally good, based upon high prices for meat and a long-term trend in this country toward an agriculture characterized increasingly by more production of beef, hogs, and poultry. Therefore, oilseed processors tend to be far more interested in the feed value of their protein meals than in either their food possibilities or their technical industrial possibilities. Distinctly the greatest contributions that can be made in this connection, most of those interviewed suggested, is the enhancement of their feed values. Thus, the research directed toward inactivating soymeal enzymes, which limited proper digestion and assimilation, is regarded as by far the main help that research has afforded to the protein end of the soy business. Similarly, upgrading the feed value of cottonseed cake to permit its use as fully as protein meals of soybeans or corn (as by physiologically inactivating its toxic pigments) is regarded as the main task of the protein end of the cottonseed business. In each instance, the contributions of the Northern and Southern Regional Research Laboratories respectively are appreciated in the trade (table 18).

Some apprehension among feed men was noted that if large-scale industrial applications of oilseed meals should be developed it might result in a shortage of protein feeds, especially in view of the large

TABLE 19.—*Oilseeds: Production, disposition, imports, and season average price per pound received by farmers, 1929–49*—Continued

Year	Flaxseed [4]			
	Production	Net imports [5]	Net supply	Price
	Million pounds	*Million pounds*	*Million pounds*	*Cents*
1929	892	1, 110	2, 002	5. 02
1930	1, 214	434	1, 648	2. 88
1931	658	773	1, 431	2. 09
1932	645	346	990	1. 57
1933	387	1, 033	1, 419	2. 91
1934	320	866	1, 186	3. 04
1935	835	862	1, 697	2. 54
1936	299	1, 459	1, 758	3. 39
1937	396	998	1, 394	3. 34
1938	450	1, 047	1, 497	2. 84
1939	1, 098	727	1, 824	2. 61
1940	1, 732	612	2, 344	2. 54
1941	1, 799	1, 179	2, 979	3. 20
1942	2, 295	271	2, 566	4. 22
1943	2, 801	331	3, 131	5. 05
1944	1, 213	[6] (184)	1, 030	5. 20
1945	1, 935	455	2, 390	5. 16
1946	1, 265	567	1, 832	7. 21
1947	2, 270	[6] (1. 3)	2, 269	10. 98
1948	2, 942	[6 8] (32. 7)	2, 909	[7] 10. 27
1949	[9] 2, 330	[6 8] (166)	2, 164	----------

[1] Excludes deliveries exchanged for meal which, in 1949, amounted to 282 million pounds and is normally 10 percent or less of total deliveries to the mill.
[2] Picked and threshed.
[3] Converted at 60 pounds per bushel.
[4] Converted at 56 pounds per bushel.
[5] Including linseed oil in terms of seed, year beginning July.
[6] Net exports.
[7] Preliminary.
[8] Foreign Crops & Markets (*26*).
[9] Estimate, Demand and Price Situation (*14*).

Unless otherwise noted, all figures 1929–46, Agricultural Statistics, 1948 & 1949 (*25*); figures 1947–48, Crops and Markets, 1949 (*12*).

and growing demand for protein meals for feeds which is overwhelmingly the largest use. They suggest that such use would tend to raise the prices of oilseed meal, thereby lessening their advantage for industrial use. Some of these feed men said they saw no reason why research should be done in this field.

Oilseed meals are intercompetitive, really, and the total quantity available is many times as large as any prospective industrial demand will be for many years to come. Oilseed meals are extremely desirable feed supplements, but they are not essential. The price of these meals depends from a demand viewpoint, essentially on feeds. On the basis of contained protein their price is considerable, in view of the processing costs needed for many purposes to make this protein useful, and the need for the finished products to meet competition from such products as starches, casein, and synthetics. However, for some existing uses, including protein fibers which are the most attractive for expansion, it seems likely that industrial users of the three most available of these meals will be able for many years to pay enough for them to obtain all they need.

For several years the supply and demand of the different oilseeds has been greatly influenced by the governmental market activities, acreage restrictions, and support prices. The relative availability and price of the various seeds, oils, and meals, are interdependent; the relationship is complicated. Thus, for example, the support price on flax makes the price of linseed oil high, thereby encouraging the use of soy oil. As reductions of cotton acreages make for an excess of cottonseed milling capacity, these millers look to alternative seeds to process. On the other hand, the support price of cotton tends to restrain the conversion of cotton land to the production of other crops.

Soy, corn, and peanut meals, among the principal oilseed meals, are of main present technical interest for industrial application. Significant industrial uses for cottonseed meal, for which its color is not disadvantageous, may perhaps be developed. Of these, only soy and corn proteins are commercial; and the commercial success of corn protein is limited mainly to its principal protein fraction, zein, which is isolated from it. Zein has characteristics, notably aqueous insolubility, which distinguish it from other oilseed proteins and from casein. Soy protein remains the material of largest use in this field, whether as the meal (as in plywood adhesives), the flour (as in wallpaper coating) or the protein isolate (as in paper coating).

The following section summarizes the status of the production of seed-protein isolate. Against this general background the principal oilseed proteins are briefly reviewed. This review is followed by a brief review of other natural and directly competitive materials, of which casein is foremost.

In evaluating the potential industrial use of these natural materials it must be recognized that it is increasingly difficult for them to compete successfully with starches and synthetics the rapid improvement of which is characterized by being based on extensive fundamental knowledge, such as is lacking for proteins. The markets for starches and synthetics have been gained both at the expense of former protein applications and in new areas which might have been entered by proteinaceous materials had they been suitably modified.

Protein Isolate Production

Soy-protein isolate—by which is meant the acid-precipitated alkaline extract of solvent-extracted soy meal—is in commercial production by three large companies, and in experimental production by two others.

Total capacity for the production of soy-protein isolate in the United States has been estimated as 25 to 30 million pounds a year. Production in 1949 is reported to have been less than half of capacity, but in the middle of 1950 two major producers were reported to have been operating at capacity, and the third commercial producer was said to be increasing the activity in this field.

Other soy-protein extracts of food grade are also in production.

Cotton-protein isolate has apparently been made only by the Southern Regional Research Laboratory.

Corn's principal protein fraction, zein, is produced as a pure isolate from corn gluten. In 1950, only one firm was producing zein. Zein capacity, as variously reported, probably approximates 5 million pounds a year.[27]

Peanut-protein isolate is being produced in Britain, from expressed peanut meal, for use in producing Ardil, a peanut-protein fiber. There is no commercial production in this country. Its experimental production by the Southern Regional Laboratory has aroused some interest that is not very active.

Production of other oilseed protein isolates appears to have been limited to small-scale laboratory experimentation.

Soybeans

The spectacular growth in volume and importance of the soybean crop accompanied the development of varieties which were easily cultivated and contained a high oil content that is well suited to processing. Soy flour, meal, and isolate are all used industrially. Soy flour, really a dehulled soy meal, is divided into three types: full-fat soy flour, which has all the fat originally found in the soybean and has not been processed for oil extraction; low-fat soy flour, made by a continuous mechanical pressing method in which the greater part of the oil is removed; and defatted soy flour, made by extraction process and containing less than 2 percent fat, with protein content ranging up to 53 percent. Soybean-oil meal contains the hulls. Expeller or hydraulic-processed meal has a minimum specification of 41 percent protein; but its content actually averages 44 percent. Solvent-extracted meal has a standard specified protein content of 44 percent, but actually averages nearer 46 percent.

Many shipments of extracted meal are reported to contain more than 48 percent crude protein, with no premium charged in spite of the fact that soybean oil meal is bought principally on the basis of its high content of good-quality protein. Within the last 4 years solvent extraction has increased from 30 percent of the total quantity processed to 40 percent.[28] Isolated soybean protein is obtained by treating soybean-protein flakes which have previously been solvent-extracted to remove their oily matter. The subsequent treatment is to remove cellulose, sugars, and other nonprotein ingredients. The yield of isolate from the meal is reported to average about 28 percent, varying between 20 percent and 40 percent. The 46 percent yield has been obtained only in the laboratory.

Nearly all of the cake and meal is used for feed. An adequate supply of soy meal for industrial use appears available as far as can be foreseen. Work to improve the nutritional qualities of the meal is continuing, such as the addition of methionine to give the ration the value of whole-egg protein.

In most industrial applications soy proteins replace casein. Both casein and soy proteins face strong competition from synthetics, which are taking over a larger part of some markets. Unless there is a

[27] Its substantial enlargement is under active study (May 1951).
[28] See footnote 25, page 93.

decided decline in the price of casein, such as may occur over short or moderate swings but is not anticipated for the long run, the industry expects soy protein, with its vast supply and relatively steady price, to find growing application in the casein market. As costs of raw material are reported to make up a greater part of the price of casein than they do of the price of soy isolate, changes in the price of the basic raw material would affect the price of soy isolate relatively less.

The price structure of the soybean industry depends upon the prices of the oil, which is in competition with linseed and cottonseed oils, and the meal, which has some direct competition from other oilseed meals and from fish and animal scrap proteins, as a feed protein supplement. It has indirect competition from feeds that have less concentrated protein content, such as grains. Feed now accounts for 80 percent of the bulk and 60 percent of the value of soybean products, and has been threatening to relegate the oil to something resembling the position of a byproduct. The reverse was formerly true. The industry expects the meal to continue to grow in importance.

The outlook for domestic supplies of soybeans is excellent. As varieties adapted to provide adequate yields are developed, the growing of soybeans for processing is being extended farther into the South where, it is said, two crops can be raised in a year, in several places, compared with one cotton crop.

Cottonseed

Cottonseed meal would seem to be a logical source of protein for industrial utilization. It is the only oilseed meal that is produced in large quantities, except for soybean meal, and on the basis of protein content it tends to be the cheapest. The high price of the oil has been a strong incentive for processors to change to solvent extraction from expeller or compression processes to get the greatest yield of oil. Meal that has been extracted sells for a slight discount, but processors expect that, after suitable nutritional and textural development, and promotion, this discount will gradually disappear. Current developments are designed to make all cottonseed meal nutritionally more desirable as feed and are likely to broaden the demand further.

There is a considerably greater demand for cottonseed cake and meal for cattle-feed supplements in the grazing areas where it is produced than the local production can meet. In spite of the need for improving the protein content of the diet of many poor people in this country, considerable doubt was expressed that cottonseed would ever be processed for human consumption on any significant scale.

As cottonseed is made available as a part of the production of cotton, governmental control of cotton acreages regulates the quantity of seed that is available. There is an excess of processing capacity for cottonseed, and additional shortages of cottonseed may encourage cottonseed processors to turn to other oilseeds for raw material.

Although the present tonnage of cottonseed meal is only half the tonnage of soybean meal, it is considerably greater than the production of any other protein feed. This suggests that, to meet the requirements of a considerable fraction of the industrial protein potential, would require the diversion, from consumption as feed, of only a minor fraction of the total production of cottonseed meal. Thus, total apparent consumption of casein is only about 1 percent of domestic cottonseed cake and meal production (on a 41 percent-protein basis, however). It is probable that processors would be rather reluctant to make this protein available for industrial use, in view of the heavy demand for feed, unless a large market could be assured at a price that would encourage upgrading the protein.

Peanuts

Although considerable technical information directed toward potential industrial application of peanut protein has been gathered, and some products, particularly textile fibers, seem to have possibilities of development from it, no appreciable industrial use in this country is now apparent. A considerable downward readjustment of costs and prices of peanuts appears necessary to the substantial realization of this potential.

Compared with production of soybeans and cottonseed, the production of peanuts in the United States is rather small. The peanuts grown are mainly of edible types. As more efficient means of cultivation and mechanized harvesting are developed to make the production cheaper, peanuts might become a much more important crop in this country. They are important crops in some countries where the cost of the large amount of labor now required is much lower, as in India. The high concentration of oil and protein in peanuts makes them a noteworthy item in international trade. The limited and highly fluctuating marginal supply available in the United States for industrial processing, plus the technical difficulties, makes isolating peanut protein here relatively unattractive. In some areas, governmental restrictions (1950) on the acreages of cotton were expected to encourage the growing of peanuts. But a very marked increase in production in cotton-producing areas of the South could not be expected, as only a limited additional area there is suitable for peanuts.

As pointed out in the section on textiles, in addition to the limitations of supply and price to the production of a protein isolate suitable for making regenerated fibers, there are many technical difficulties. Despite contrary British claims, only solvent-extracted relatively undenatured protein is generally considered suitable for industrial use. The development of satisfactory methods of solvent extraction has not taken place. The skins must be removed to produce a light-colored protein. The residues from extraction must be disposed of.

Peanut meal is customarily made by crushing, which produces a partially denatured meal with about 45 percent protein, some of the protein having been damaged by the heat developed during cooking and pressing. Various sources indicate that progress is being made in the development of solvent extraction, and in reducing the color retention of extracted peanut protein. This gives a material that is more suitable for industrial purposes. Some small-scale commercial solvent extraction has produced a meal with about 55 percent available protein. As peanut shells normally are incompletely removed before the processing, or are later added to peanut meal which is intended for use as feed, to approach the minimum protein (Nx6.25) requirement of 45 percent, manufacturers of peanut meal should have no difficulty in preparing a meal that contains 50 percent or more protein.

It is reported to be difficult for processors, particularly the smaller companies, to obtain adequate supplies of peanuts that are suitable for making an undenatured meal. The high cost and limited supply reflect the fact that production of peanut oil, cake, and meal, is the marginal part of the peanut industry. Food uses are far more important. Any peanuts that are available for oil extraction come mainly from surpluses. Restrictions on production and price-support programs are designed to avoid surplus production and to prevent the depression of prices to producers when surplus supplies occur. The high nutritional value of peanuts coupled with their acceptance as foods, not merely as feeds, may permit expanding their food uses, for instance by developing edible peanut flour and meal. Total production of cake and meal is only about 2 percent of the total production of soybean cake and meal. Until larger quantities of peanuts are regularly available for industrial processing at lower and more stable prices, any development of solvent extraction and isolate production on a scale sufficient to supply an industrial market seems unlikely.

Zein and Corn Gluten

Zein is extracted from corn gluten, which is a byproduct protein concentrate obtained during the wet milling of corn. An adequate supply of corn gluten is available for producing enough zein for all foreseeable needs. Enough corn gluten was milled in 1949 for about 350 million pounds of zein, and this use is considered sufficiently profitable to warrant diversion of gluten from its excellent market in mixed feeds.

The wet-milling industry has been processing between 110 and 130 million bushels of corn annually (table 20). The quantity of gluten feed and meal produced is directly proportional to the wet-process grindings.

Table 20.—*Corn: Wet process grindings, and production of gluten feed and meal, 1939–49*

Year	Wet process grindings	Gluten feed and meal	Year	Wet process grindings	Gluten feed and meal
	1,000 bushels	*1,000 tons*		*1,000 bushels*	*1,000 tons*
1939	77,244	592	1945	119,053	824
1940	81,727	624	1946	120,611	872
1941	110,293	819	1947	139,273	1,015
1942	130,330	1,013	1948 [1]	109,878	781
1943	128,455	911	1949 [2]	116,175	
1944	119,928	827			

[1] Preliminary.
[2] Survey of Current Business, *(22)*.

Agricultural Statistics, 1949 *(25)*.

The actual yield of zein is 1½ pounds per bushel of processed corn.[29] On the basis of wet-processed production in 1949 of 116 million bushels, this would give raw material available for approximately 175 million pounds of zein. That this is probably as much as will be needed for the production of zein for many years is suggested by comparing its only really large potential use now apparent, regenerated zein fibers, for every pound of which about one pound of zein is used, with total mill consumption of wools in the United States.[30]

In 1949, consumption of zein for regenerated fibers was reported as 4 million pounds; a rate of 7 million was predicted for the end of 1950 and of 15 million by the end of 1951.[31] This would be equivalent to processing the corn gluten from 5 million bushels of wet-milled corn, or somewhat less than 5 percent of the gluten potentially available from current production.

The corn wet-milling industry has a capacity of 420 thousand bushels a day, producing enough gluten to be processed for 1,250,000 pounds of zein a day.

The corn-milling industry consumes only about 4 percent of the annual corn crop. The price of corn does not affect the profit realized by the industry until it reaches a point that products from this industry cannot compete with products from other industries, such as vegetable and animal proteins, synthetic resins, silicates, and cane-sugar products. Prices of the chief products fluctuate with the price of corn to maintain levels of earnings. The quantity of feeds produced clearly depends on the total quantity of corn processed. Production of corn starch and its derivatives—corn syrup, dextrose, and dextrines—depends upon demand. The limiting product of this industry tends to be the starch which must compete with other starches in industrial uses.

Unlike the other principal seeds of which the oil is the primary product, corn is valued mainly for its starch.

The low price of the protein when sold as gluten feed and meal makes any upgrading in value rather attractive even though present prices for feed and meal are rather high and demand is far from satisfied. Corn-gluten feeds must compete in price with other protein-feed supplements which are available in considerably greater quantity. Gluten feed that had 23 percent protein sold at about $50 per ton in 1949, and 41 percent meal at $70 per ton. Thus, allotting the entire value to the protein and none to the bran, 1 ton of 23 percent feed has 460 pounds of protein valued at 11 cents a pound. On the same basis, 1 ton of 41 percent meal would contain 820 pounds of protein worth 8½ cents a pound. Zein sold at 30 cents per pound in 1949. Although only a part of the protein in the feed and meal from which it is extracted is recovered, the unrecovered protein may still be disposed of in feed.

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[29] Although it is true that a bushel of corn contains about 3 potential pounds of zein, under present and future methods of recovery, yields of about 1½ pounds as used in the calculations are a more realistic figure.

[30] During 1948, on a scoured basis, this was 485 million pounds (apparel class) and 208 million pounds (carpet class.)

[31] Limited capacity for production of zein has so far prevented expanding production of regenerated zein fibers beyond about 4 million pounds per year. Expansion of zein capacity is under active present (May 1951) study.

Prices of zein have been held relatively stable, in comparison with prices of corn gluten, which vary widely depending upon prices of competitive protein feeds and of corn. This difference in degree of fluctuation is indicated in table 17 on page 95, a calculated price of zein based upon price of 23-percent gluten feed; and the actual price of zein.

Based on the current outlook for zein in comparison with other industrial uses for corn gluten, it is reasonable to assume that most corn gluten that is processed will be available for the production of zein. Discussions in the trade tend to confirm this assumption. Increases in the use of corn gluten for the production of monosodium glutamate are likely to be very small in comparison with the available supply. A few million pounds of corn gluten are used annually as an emulsion stabilizer for water-based paints. Other industrial markets for unmodified corn gluten do not now appear to be very attractive.

It has been suggested by those interviewed that there is a problem of protein balance in corn processing, whereby greater industrial utilization of corn gluten would result in too much bran for good feed formulas. Even should enough gluten be needed industrially at somewhat better margins to cause an appreciable surplus of bran, the industry appears to be willing to upgrade its corn gluten in this way, though this might throw its feed business out of internal balance.

Flaxseed

The production of linseed meal is about one-tenth by weight of total oilseed cake and meal produced in the United States. It contains 35 percent protein and a high mucin fraction which make it very viscid. This means special difficulties when the protein is recovered from the meal.

So far, no industrially desirable characteristics seem to have been found in linseed protein which differentiate it sufficiently from other proteins to make feasible its isolation for industrial use, considering its low protein content and considering that satisfactory feed uses have already been developed. Unless some value could be discovered in the mucins, it does not seem probable that processors will develop the protein isolate.

The production of flaxseed has been increasing steadily and is being extended to new regions. Although the Gulf Coast still supplies only a minor fraction of the total production of the United States, the growing of flaxseed is spreading rapidly there. Flaxseed is favored by its ability to withstand hurricanes better than cotton; by restrictions in cotton acreage which free much land for its planting; by existing cottonseed-mill capacity which can operate on flaxseed; by the crop's ability to grow on soil not rich enough for good yields of corn, cotton, or small grain crops; and by its contra-seasonality which is popular with both farmers and processors. Production of flaxseed has been very generally mechanized.

Before World War II the imports of seed often exceeded the exports; but this margin has declined, and since 1947 the exports have been greater than the imports by an increasing quantity, reflecting both the acute shortage in Europe and the aid extended by Economic Cooperation Administration.

Although at present more than half of the flaxseed processing is by screw-press or expeller method, the trade thinks that soon very little expeller capacity will remain in this country and it will be operated only marginally in years of unusually high production. Expeller meal commands some premium over solvent-extracted meal, but this difference in price is declining. In any event, it does not make up for the loss of oil by the older process. Linseed meal is used almost entirely for feed. It is said by some processors to be particularly good in finishing livestock to give a glossier coat and healthier look; but some opinions indicated that it is disliked by stock feeders until they learn to appreciate its good points.

Wheat Gluten

The prospect for any substantial industrial use of wheat gluten is limited mainly by the market for wheat starch, by the high cost of the gluten, by its dependence on the supply of second clears from which it is produced, by the lack of understanding of the basic nature and properties of the gluten, and by technical difficulties in producing an undenatured protein. Because of these deterrents, work related to the effect on baking characteristics of the gluten that is naturally present in blended flours is generally considered to be more encouraging than work on industrial uses of wheat gluten. If some uniquely useful property should be found capable of being made available at a reasonable price, this might not be true.

Its only unique property noted by researchers is its tremendous capacity for absorbing water—just the reverse of keratin protein. Gluten sulfates and phosphates have been made which are insoluble in water, yet when they are in water they swell to 200 to 300 times their original size. But their cost, estimated by a major gluten producer as more than $2 per pound, was too high in 1949 for their anticipated use in cosmetics compared with competing materials such as vegetable gums or carboxymethyl cellulose. Because wheat gluten has considerable color it tends to compete with less expensive gums. Extensive exploration by drug firms has indicated that even though gluten would need to be cleaned up considerably if put to pharmaceutical use, it could be produced for much less than $2 a pound on a commercial basis. Nevertheless, it still seemed unattractive to those interviewed. The main threat to this entire group of products appears to be carboxymethyl cellulose and related compounds which are clear and nonfermenting, and which afford no support to bacteria.

For most conventional uses, wheat gluten seems ruled out because of its high cost, arising from the problems in drying it in a nondenatured condition. This is a difficult problem, considering its affinity for moisture. It should be dried undenatured because when denatured it loses its excellent tack and other desirable properties. In view of current progress in vacuum drying, the possibilities of economic drying of an undenatured product may some day be worth exploring again. A basic limitation of wheat gluten, however, is its tendency to become denatured later, no matter how well it is initially prepared. If the gluten could be stabilized its use as an adhesive would be decidedly promising.

The only present established use for the separated protein is in the production of monosodium glutamate. This is technically the best reasonably available source of glutamic acid, but because of the limited supply and the high price of this source more of its production is shifting to the recovery from the proteins of beet sugar, soybeans, and corn.

The addition of gluten to lower-gluten flours in bread making to offset gluten deficiencies in low-gluten wheat might be considered except that it is currently uneconomical to dry the gluten without changing its properties enough to make it useless for this purpose. One of the most attractive potential uses of wheat protein has been suggested as in paper coating. One large producer has been aiming to sell relatively undenatured wheat gluten for industrial use as paper coating at a price of about $0.25 to $0.30 per pound which is $0.05 to $0.09 above the cost of ordinarily dried (denatured) gluten such as is now used in monosodium glutamate production. The price will have to be based on the price of second clears.

Second clears are fractionated into purified wheat starch and wheat protein (gluten), which tends to be a byproduct. There is a considerable difference in the protein from different strains of wheat. Any substantial industrial use of wheat gluten is limited by the supply of second clears, processed for starch, because these contain only 8 percent protein. The market for wheat starch is said to be growing, but at a slow rate. About 2 percent of the wheat that is milled consists of second clears. Patent and first-clear flours are used for baking and related uses. Second clears are reported to be enough off-color and off-grade in performance to constitute a marketing problem, being in the end neither a flour nor a feed.

Price of second clears makes the development of uses relatively unattractive at present, particularly in competition with casein. The situation in the State of Washington may be unique in that surpluses of wheat may accumulate because of the restricted market in this country for the type grown there, and the poor outlook for export to the Orient.

Research on wheat proteins has been advocated by members of the milling industry in view of the size of the industry and the large number of establishments engaged in processing wheat for starch and protein. If research could determine the nature and structure of the proteins in what gluten in relation to its doughiness, the relation of denaturation to its solubility, the mechanism of denaturation, means for decreasing gluten's cohesiveness and increasing its adhesiveness—if all this could be done, the development of various large-scale applications would be much more feasible than is true at present.

Sunflower, Safflower, Sesame

The expectation (late 1949 and early 1950) of continued acreage allotments for wheat and cotton has encouraged much development work with sunflower, safflower, and sesame seeds. If the production of cotton is reduced to approximate the domestic demand, the excess capacity of cottonseed-oil crushers will force processors to turn to nonfibrous oilseeds for their raw material.

Because of the high protein content of the sunflower, direct use of its meal as an adhesive and as a source of isolate production might appear to be reasonable; but the survey did not reveal any such usage. Sunflower seed is produced in large volume in other countries, as Russia and Argentina; but industrial use of its meal there is unknown.

Sunflower seed is potentially an important domestic source of oil and protein. Seeds average about 28 percent oil content, 36 percent hull, and 36 percent meal. The oil is comparable to soybean oil but is free from linolenic acid and flavor reversion. The meal has a higher protein content (52 percent) than any other common oilseed meal. Sunflowers can be grown successfully in all parts of the United States and are resistant to drought and frost. They require no labor from sowing until harvesting, but need a great deal of labor at harvest. If this labor requirement could be reduced through mechanical harvesting, sunflower seeds might become an important oilseed crop. Efforts are being directed to developing dwarf varieties and using hybrids of these that will produce an abundance of seed that will be high in oil content and which can be easily harvested. Yields range from 200 to 2,000 pounds per acre and average about 1,000 pounds.

The production of safflower seed, though small (more than 30 million pounds for crushing in 1949), is increasing rapidly. Safflower shows promise as a commercial crop in the Pacific Northwest and in the Great Plains States from Arizona to western North Dakota. It grows best in areas that have an annual rainfall from slightly under 9 inches to 20 inches. It is harvested by standard combines. Typical yields are about 700 pounds per acre. The seed of newer strains consists of about 35 percent oil, 40 percent hull, and 25 percent meal. It is reported as excellent as a feed for livestock and poultry. It is produced primarily for its oil, which is sold mainly to paint manufacturers for a drying oil. Its price depends on the price of linseed oil. It lies between soybean and linseed oils in its drying properties. The protein content varies, depending upon the processing method used. Meal from screw-type presses has about 20 percent protein content; meal from some of the newer seed varieties has up to 25 percent protein. Meal from completely dehulled seeds may contain more than 60 percent protein. Solvent extraction can be used, giving a meal that is slightly higher in protein content, although the most processing is now done with screw presses without removing the hulls. These meals find a ready market in the local livestock-producing areas.

Sesame is an excellent oilseed-producing plant that will grow well in some areas of the United States. Breeding of improved seeds is active, to give strains with seed pods which open uniformly when ripe and do not scatter the seed before the harvest. The oil is of high edible quality. Sesame-oil meal contains about as much protein as cottonseed meal, averaging about 43 percent, and supplies protein of good quality for feeds.

Casein Situation

Oilseed proteins have won most of their industrial markets by displacing casein, and most prospective increases in their use depend on further displacement of casein. But the development of a new fiber from oilseed proteins and corn gluten and entirely new uses will not depend upon replacing casein for its market. Casein and soy isolate are more or less interchangeable for many of their applications. The choice between them by experienced users commonly depends on their relative prices. For these reasons the trend of future availability, quality, and price of casein, is of importance in evaluating the prospective industrial usage of oilseed proteins.

Because it has been more profitable to most producers to use skim milk for food or feed purposes than for making casein, the production of casein in this country has declined from a prewar level of about 40 to 50 million pounds, representing three-fourths or more of the apparent consumption in the United States, to 20 million pounds in 1949, representing about one-third of consumption in the United States. This increased use of skim milk for human food has been a long-term trend. The Government's purchase of dried skim milk to help support the price to farmers for milk used in manufacture, at times has acted to channel more solids not-fat of milk into production of dried milk rather than casein.

The short-term outlook for the industrial utilization of casein is primarily dependent on price, for the over-all consumption is rather sensitive to changes in price. For example, a reduction in the price of casein in early 1949 was accompanied by a marked regaining of business lost to soy isolate for paper coating. The consensus of the trade interviewed was that the limited market for lactose, obtainable from whey, a byproduct in the manufacture of casein, will not be a significant limitation to the production of casein except in sporadic instances.

In general, casein markets are faced with increased competition from soy isolate and synthetics, and the increased use of starch in paper coating and so are declining.

Although the long-term trend is for a declining production of casein in foreign countries as well as here, the intermediate outlook, now that world agriculture is in a more normal situation, is for increased foreign supplies, of better quality. The general trend of production of casein in the United States during the last 10 years has been downward, and the trend of imports has been upward. The apparent domestic consumption has fluctuated decidedly during the last 20 years—from a low of 26 million pounds, practically entirely domestic production, in 1932, to a high of 89 million pounds in 1941, approximately equally divided between domestic production and imports. Except for 1941, during the last decade the total available casein has ranged approximately between 50 million pounds and 75 million pounds annually. In 1939, imports accounted for 28 percent of the total whereas in 1949 they had increased to 62 percent.

Production does not vary with demand because the skim milk from which casein is made, frequently is converted into other products at greater profit. This condition has prevailed since before the outbreak of World War II. The rise in consumer disposable income and governmental subsidies caused a sharp increase in the production of milk during World War II and induced a much higher percentage of the total production to be delivered as whole milk. Since World War II, farm price support programs for dairy products have resulted in purchases of skim milk powder by the Commodity Credit Corporation that reached a record total, in 1949, of approximately 442 million pounds; they were approximately 150 million pounds in 1948.

A government purchase price for skim milk of 12 cents means that domestic casein must sell for 25 cents. This limits domestic production to surplus quantities. An additional deterrent to the production of casein has been the increase in cheese production—the total in 1949 exceeded that of the previous year by approximately 80 million pounds. A decrease in butter production of 39 percent from 1939 to 1949 has also reduced the available supply of separated milk (*11*).

The relative change from 1939 to 1949 in manufactured dairy products (based on U. S. D. A., *Production of Manufactured Dairy Products, 1949*) (*20*) shows the trend toward using skim milk for other products than casein. During this period, in which the production of domestic casein decreased 55 percent, manufactured skim and buttermilk products increased 79 percent, and production of other skim-milk manufactures increased as follows: nonfat dry-milk solids, 134 percent; condensed and evaporated skim milk, 106 percent; concentrated skim milk for animal feed, 20 percent; full-skim American cheese, 500 percent. The relatively high proportion of manufacturing milk used in evaporated milk and cheese has limited the supply of milk available for other manufactured dairy products.

Over the next few years a continuation of the long-time upward trend in the rate of milk production is expected (*11*). In addition, farmers will probably sell a larger proportion of their milk as whole milk, thereby increasing the supply of factory-separated milk. The extent of this increase will depend upon the demand for factory-separated cream and skimmed milk products relative to whole-milk products.

Consumption of foods containing skimmed milk is tending to increase as people are becoming aware of the need for regular consumption of larger quantities of the nutrients supplied by the dry-milk solids nonfat. This trend is expected increasingly to limit the quantity of skimmed milk available for casein production and to emphasize the importance of casein imports. The total domestic disappearance both civilian and military of dairy products in 1949 was about 114.4 million pounds, an increase of 10 percent over 1935–39 average. Per capita civilian consumption of fluid milk and cream increased 12 percent between 1939 and 1949; condensed and evaporated milk increased 11 percent and dry whole milk increased 115 percent (*11*).

The importance of nonfat dry-milk solids as a dairy product in the United States has increased considerably through the emphasis given it by emergency food programs during the war and price-support programs since the war. The output of nonfat dry-milk solids has more than doubled during the last 10 years, and according to a recent study long-range production prospects are for further increases (*2*). Almost two-thirds of the annual production of more than 800 million pounds of nonfat dry-milk solids in recent years has been used in the United States and the rest has been shipped abroad. Domestic production during 1949 was nearly 900 million pounds. In the immediate prewar years the annual output for human use averaged about 250 million pounds compared with 25 to 40 million pounds in the early 1920's. The available supply of nonfat dry-milk

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solids increased from 373 million pounds in 1941 to 656 million pounds in 1948 (*13*).

The production of dry casein in 1949 totaled 20.3 million pounds, a gain of 41 percent from 1948 but a decline of 43 percent from 1947 (*15*). The output in 1948 was 60 percent lower than the output in the preceding year and, except for 1945, was the lowest on record during the last 25 years. Manufacturers' stocks of dry casein at the end of 1949 were 1.35 million pounds—a record low for the date, being 16 percent lower than a year earlier and 58 percent lower than the 5-year average on December 31. Holdings were near the record low in 1947 of 1.28 million pounds. They were as high as 9 million pounds in 1942 (table 21).

Relative price increases from 1940 to 1950 are as follows:

Casein	134 percent increase
Zein	50 percent increase
Soy-protein isolate	33 percent increase

TABLE 21.—*Casein, dry: Available supply, and price per pound received at New York, 1929–49*

Year	Production	Imports for consumption	Total supply	Price ground, New York
	Million pounds	*Million pounds*	*Million pounds*	*Cents*
1929	30.5	27.6	58.1	15.6
1930	42.0	18.5	60.5	13.1
1931	35.3	3.5	38.8	7.6
1932	24.4	1.2	25.6	6.3
1933	24.1	8.1	32.2	11.0
1934	37.3	1.5	38.8	11.8
1935	37.6	3.2	40.9	12.2
1936	46.1	16.2	62.3	16.1
1937	67.5	5.2	72.7	14.7
1938	48.5	.4	49.0	8.6
1939	40.9	15.8	56.7	12.0
1940	46.6	24.5	71.1	12.6
1941	47.3	41.5	88.9	21.4
1942	42.3	16.8	59.1	20.6
1943	18.4	28.0	46.4	22.4
1944	15.3	47.2	62.5	24.4
1945	12.3	51.6	63.9	24.0
1946	18.3	45.3	63.7	[1] 24.0
1947	[2 3] 35.8	20.9	56.7	[1] 30.0
1948	[2] 14.4	[4] 40.6	55.0	[1] 34.0
1949	[5] 20.3	[4] 33.0	53.3	[1] 30.0
1950	[5] 19.2	34.5	73.7	[1] 29.5

[1] Spot price at beginning of year; domestic, acid-precipitated, bags, 5 tons or more, shipment point, Oil, Paint & Drug Reporter. Prices in January 1950 for standard quality were 23–23½ cents per pound in New York City according to the Production & Marketing Administration.

[2] PRODUCTION OF MANUFACTURED DAIRY PRODUCTS, (*20*).

[3] Revised.

[4] MARKET REVIEW OF CASEINS, ROSINS AND RESINS (*29*).

[5] Revised estimate; MILK PRODUCTION ON FARMS AND STATISTICS OF DAIRY PLANT PRODUCTS 1949 (*19*).

Unless otherwise noted, Agricultural Statistics (*25, 1949*).

Since soy-protein isolate and casein have become interchangeable in many applications, the availability of the soy isolate in quantity at a relatively stable price has tended to put a ceiling on the price of casein and has dampened the fluctuations in price which formerly characterized casein.

The limitations on the production of domestic casein have placed increased emphasis on imports to meet demand. Although domestic producers are usually the big importers of casein, the duty remains at 2¾ cents per pound. Argentina continues to be the principal source of imports, having supplied approximately 85 percent of the total imports in 1939, 90 percent in 1943, 95 percent in 1946, 91 percent in 1947, 85 percent in 1948, and 84 percent in 1949. Small supplies have been obtained from France (several hundred thousand pounds in 1949), New Zealand (2½ million pounds), and Canada (1½ million pounds). Casein from some of the countries reentering the export market, as New Zealand and Holland, is of the exceptionally high quality required for fiber production comparable to the best domestic casein. The cost of casein from Holland and New Zealand is less than that of good domestic casein by approximately 2 cents a pound. Casein from Argentina is likely to be of poor-to-medium quality. French and Danish casein has been of low quality but these sources hope to produce a more satisfactory product soon. Imports from these countries (except Argentina) have recently begun and are still in small quantity but these countries expect to increase the quantity available for consumption in the United States in the near future.

Egg Albumen

The price of egg albumen has been sufficiently high and sufficiently fluctuating to encourage the use of other materials, including some soy-protein fractions, and the development of synthetic albumins from other protein materials, such as the Norwegian production of a synthetic albumen from codfish waste. Government price supports and marketing activities have affected the production and price of egg products. Large supplies were formerly obtained from China, but that country has not been an important source for several years.

The industry expects a gradual increase in the use of dried eggs at the expense of frozen, this to be accelerated if the fundamental work at the Western Regional Research Laboratory is successful on pretreating the egg white before spray drying. Tables 22 and 23 show egg production in the United States and disposition, and cold-storage holdings of shell eggs, frozen eggs, and dried eggs.

Virtually all egg albumen finds application in food products. The bulk of the frozen-egg supply is preferred by the baking industry because of leavening and coagulating properties, while most of the dried egg is used in the confectionery industry where coagulating and whipping properties are necessary. Diverse industrial applications are usually filled by technical egg white, obtained in egg-breaking from treating the shells to remove the last adherent white. About 10 million pounds are produced yearly. Some encouraging results have been obtained in preparing from egg albumen a fiber for surgical sutures, but the requirements for this use are numerous and severe.

TABLE 22.—*Disposition of liquid eggs, and production of egg whites and dried eggs, 1938–50*

Year	Disposition of liquid eggs [1]			Production			
	Frozen	Dried	Frozen eggs later dried [2]	Egg whites [1]	Dried eggs: Whole	Dried eggs: Albumen	Dried eggs: Total [3]
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1938	116, 100	22, 300	--------	46, 723	179	1, 510	6, 002
1939	177, 144	31, 000	--------	68, 286	184	2, 305	10, 039
1940	189, 578	27, 050	--------	70, 845	392	1, 916	7, 487
1941	237, 182	165, 972	--------	94, 932	31, 241	4, 391	45, 280
1942	257, 631	731, 046	115, 752	70, 654	226, 127	2, 253	235, 649
1943	412, 615	782, 080	159, 346	78, 151	252, 903	2, 093	261, 974
1944	511, 791	1, 009, 402	179, 146	84, 343	311, 369	2, 310	320, 742
1945	397, 580	265, 287	122, 167	77, 893	96, 988	1, 710	105, 862
1946	392, 218	375, 945	84, 219	108, 402	115, 344	2, 112	125, 444
1947	371, 096	295, 567	20, 538	89, 114	80, 037	1, 493	85, 561
1948	345, 192	140, 048	25, 311	107, 503	36, 018	2, 678	44, 275
1949	[4] 315, 460	249, 375	--------	--------	66, 650	2, 160	74, 648
1950	[4] [5] 154, 655	68, 270	--------	--------	17, 870	675	19, 578

[1] In terms of liquid eggs.
[2] Included in "Frozen."
[3] Includes yolk.
[4] Preliminary figures.
[5] First 3 months of 1950.

1938–48, Agricultural Statistics (*25, 1949*).
1949, LIQUID, FROZEN AND DRIED EGG PRODUCTION (*17*).

KERATIN

Because of the keratinous nature of wool itself, considerable interest has been shown in the use of waste keratin for making regenerated fibers. Keratin is the base protein in hoofs, horns, feathers, scales, wool, hair, etc. It is available in many millions of pounds annually and should be readily capable of economic collection from many sources, such as wood waste, low-grade shoddy, feathers from poultry-packing houses, and hair recovered from slaughterhouses and tanneries.

It is estimated that about 100 million pounds of feathers are available yearly in the United States.

Keratin fibers have physical properties that are exceptionally attractive to the industry.

Developing a satisfactory bristle to replace the uncertain, high-priced, and diminishing supply of hog bristles used in brushes would be desirable, as other substitutes, such as nylon, Caslen, and cellulose-acetate bristles, are not wholly satisfactory.

A protein product from degraded wool, solubilized keratin, reprecipitated and regenerated, is being used in commercial quantities as a substitute for egg and blood albumin in textile printing. Other uses competitive with casein may be developed.

TABLE 23.—*Cold-storage holdings of shell, frozen, and dried eggs, annual high and low points, 1939–48*

Year	Shell		Frozen		Dried [1]	
	High Aug. 1	Low Feb. 1	High Aug. 1	Low Mar. 1	High	Low
	1,000 cases	*1,000 cases*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1939	7,024	136	144,359	44,476	--------	--------
1940	7,784	57	154,947	38,070	--------	--------
1941	6,641	297	195,187	45,239	--------	--------
1942	[2] 7,935	331	290,529	73,766	--------	--------
1943	[2] 8,871	214	351,169	56,508	--------	--------
1944	[2] 11,335	[3] 675	388,547	[4] 81,712	[5] 110,137	[4] 42,647
1945	[2] 6,120	296	[2] 255,936	[2] 85,499	[6] 111,101	[7] 20,066
1946	[2] 9,871	[3] 113	[2] 265,050	[4] 111,721	[7] 20,339	[8] 7,003
1947	4,268	[6] 221	241,573	73,564	[2] 43,775	[3] 10,376
1948	[2] 5,669	[3] 196	[2] 266,748	120,665	[3] 33,207	[2] 3,865

[1] Statistics of dried eggs were not gathered prior to 1944.
[2] July 1.
[3] Jan. 1.
[4] Feb. 1.
[5] Dec. 1.
[6] Mar. 1.
[7] Oct. 1.
[8] Aug. 1.

1938–48, Agricultural Statistics (*25, 1949*).

Calcined feathers are being tested for a variety of purposes: as a source of amino acids, for partial hydrolysis as a foaming agent, for use in soy-blend glues for plywood instead of tankage, as a substitute for horn and hoof meal as a plaster retarder, for feather adhesives comparable to hide or bone glue, and for improving the arc resistance of phenolic resin compositions.

Thus, the potential industrial applications of keratin are numerous; the supply of raw material is essentially of waste products which are plentiful and cheap.

GLUES

The long-term trend in adhesives is away from protein glues and toward synthetic resin glues, which are accounting for a growing share of the market for adhesives. Since 1920, starch has been a serious competitor with animal glue on a price basis; later resins have competed on a quality basis. Since 1920, adhesive uses of starch have increased about eight times, and those of resins several hundred times, whereas the use of glues has only doubled. Glue has the important intrinsic advantage of immediate gelation when it cools, with a further strengthening of the adhesive bond as water evaporates. Gelatin is a high-grade but not necessarily a high-test animal glue; however, not all glue-stock can be upgraded to gelatin. Generally, industrial applications for glue and gelatin are declining.

Resins are used for water-resistant shipping containers. For fiber milk containers, which constitute a major adhesive outlet, a vinyl hot-melt adhesive is now used at the rate of about 3 million pounds annually. Containers for frozen foods also use a vinyl hot-melt adhesive. A combination of glycerin and gelatin has been used for sealing the double-edged lid on cans for paints, solvents, lacquers, chlorinated solvents, etc. But for most can sealing a general-purpose sealing compound, consisting of rubber, pigment, and resin, is preferred.

ANIMAL GLUE.—Available figures on domestic production of animal glue, and hide, extracted-bone, and green-bone glues, are summarized in table 24.

TABLE 24.—*Production of hide and bone glue, specified dates*

Year and period specified	Animal glue: Hide	Bone: Green	Bone: Extracted	Bone: Total	Total
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1929	54, 329	37, 212	14, 840	52, 052	106, 381
1937	60, 304	47, 496	13, 327	60, 823	121, 127
1939	52, 403	37, 108	11, 581	48, 689	101, 092
1942	72, 914	(1)	(1)	66, 337	139, 251
1943	62, 213	51, 536	12, 930	64, 466	126, 679
1944, Jan.–June	32, 873	29, 001	9, 412	38, 413	71, 286
1946	62, 438	50, 809	15, 160	65, 969	128, 407
1947	67, 861	71, 331	18, 084	89, 415	157, 276
1949, July–Dec	25, 783	(1)	(1)	(1)	(1)
1950, Jan.–Mar	15, 771	(1)	(1)	(1)	(1)

[1] Not available.

1929, 1937, 1939, CENSUS OF MANUFACTURERS (*23, 1939*) excepting 1929 hide glue and extracted bone glue from GLUES, GELATINS, AND RELATED PRODUCTS. (*27*) and same items for 1937–39 estimated from 1936–39 data in this bulletin; 1942, 1943, 1944, and 1950, ANIMAL GLUES AND BONE BLACK (*24, M19.2*); 1949 CHEMICAL AND DRUGS (*21*).

Animal proteins used for glues include collagen, ossein, and blood. Collagen is obtained from either skins or bones, and is processed to give various grades of glue; the most refined grades are termed gelatin. Blood is sold whole as either soluble (that is, spray dried) or insoluble blood, or it is split into serum and blood albumin (hemoglobin). As these proteins are byproducts, the supply of animal proteins depends on the activity of the meat-processing industry rather than on their own demand; but supplies are ample for present needs. Collagen and blood that are otherwise not utilized are sold as tankage for fertilizer and feed.

Hide glue is made from the skins, and extracted-bone glue is made from the bones of animals. The former is usually the more expensive. They are used primarily in the manufacture of furniture, surface-coated abrasives, printers' rollers, gummed tape, and paper products. Approximately as much hide glue is produced as bone glue, and is of better quality and is higher in price. According to the United States Tariff Commission, approximately 95 percent of the raw material consumed in the manufacture of this glue is of domestic origin. Slightly more than half the raw material used in the production of extracted-bone glue has been of foreign origin.

Demand for bone glue has been relatively well maintained, especially from manufacturers of paper boxes, luggage, and gummed tapes. The production of hide glue appears to be sufficient for present needs.

Whole blood is used in the plywood industry to the extent of 3 to 4 million pounds a year. About one-third of the total domestic consumption of blood albumen (of 1 million pounds a year) is estimated to be used in spotting corks in bottles and can tops.

The largest consumer of spray-dried blood is the plywood industry, which uses it with soy meal. Insoluble blood goes chiefly to feed and fertilizer markets. Some blood is split into serum and hemoglobin, the serum competing directly with egg albumen in nonfood uses, such as spotting corks to crown caps or treating shoe leather for uppers. Hemoglobin has various special adhesive applications.

Glue sizes are thin, weak glues which are mixtures of glue and various other materials depending upon the use to be made of the product. Animal-glue sizes are used chiefly for sizing walls, carpets, burlap, wall coverings, and straw hats.

Fish glue, made from fish skin and related wastes, is used mainly in photo-engraving, making gummed paper, woodworking, and in the household. Most of the production is accounted for by one company which declines to release any production figures. In 1946, it is estimated that production of fish glues totaled 2.3 million pounds.

Starch-based glues are cold-work adhesives made principally from tapioca flour and cornstarch. They are used predominantly in machine sealing of cartons and food packages, in packaging of food, and on stamps and envelopes. They are generally the lowest priced glues. During the last 20 years, domestic production is reported to have ranged mostly between 100 and 200 million pounds per year—usually near the higher figure.

Before World War II the principal source of raw material for making vegetable glues was tapioca flour which was imported duty-free and made into glue in this country. The postwar supply of tapioca flour has been small and of low quality which has led to a shift to adhesives made from corn dextrin. Total production of dextrin adhesives, in 1947, was 78,274,000 pounds. Dextrines are used widely in sizing papers and textile fabrics, and in textile printing and finishing as well as in adhesives. They compete to some degree among themselves and with animal and synthetic glues. The United States Bureau of Printing and Engraving formerly used a 64 percent solution of tapioca dextrin; but since the war tapioca from Indonesia has not been acceptable for their purposes. The Bureau reports that waxy maize, white-potato starch, and sweetpotato dextrins, are all as good as tapioca but that there are not enough of these for their use. They are now using corn dextrin which is not so satisfactory as tapioca as it is thixotropic and has poor characteristics of flow when used in high concentration.

Gelatin

The output and use of gelatin is very diverse; but the preponderate quantity is used for the production of gelatin dessert powders, as indicated in table 25 which gives the available production figures of edible, technical, pharmaceutical, and photographic gelatins for recent years.

Gelatin is made from calfskin, pigskin, and ossein. It is sold on the basis of gel strength.

As the prices of raw stock for nonedible gelatin have increased, glue manufacturers have been competing to an increasing extent with edible-gelatin manufacturers for raw stocks that are normally used only for making edible gelatins.

Table 25.—*Production of gelatin, specified dates*

Years and period specified	Edible	Technical	Pharmaceutical	Photographic	Total: Excluding photographic	Total: Including photographic
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1929	18,423		[1] 1,713			20,136
1937	22,021	3,231	4,242	4,242		29,494
1939	22,373	4,747	2,204	2,204		29,324
1943	29,339	2,062	3,332	7,113		41,846
1945	25,591	1,316	3,364	7,702		37,973
1946	25,631	1,958	4,893	8,254		40,736
1947	32,438	2,269	3,233	7,718		45,658
1948, Jan.–June	19,104	1,841	1,690	4,098	22,635	26,733
1949, July–Dec.	13,451	334	1,499		15,276	
1950, Jan.–Mar.[2]	7,711	240	669		8,620	

[1] Includes technical and photographic.
[2] January and March only; February not available.

1929, 1937, and 1939, CENSUS OF MANUFACTURES, Department of Commerce (*23, 1939*), excepting the technical data for 1937 and 1939 which is from GLUES, GELATINS AND RELATED PRODUCTS (*27*), and SUMMARIES OF TARIFF INFORMATION (*28*), 1943, 1945, and 1946–50. GELATIN (*24, M19M.1*).

Photographic and pharmaceutical gelatins are of the same general quality as edible gelatin. About 60 percent of the edible gelatin in the United States is consumed as jelly powders; about 35 percent in ice cream, candy, and cookies; 5 percent in meat packing, dairy products, and other miscellaneous uses. Photographic gelatin is especially purified for making photographic plates, film, and paper. It is usually more expensive than food gelatin, but imperfect batches may be sold for human consumption at the lower price. Pharmaceutical gelatin, which must comply with the standards of the U. S. Pharmacopeia, is used mainly in making capsules. Before the war considerable quantities of high-grade gelatin were imported from Belgium, Holland, France, and Germany. Since the war imports have been much smaller.

Some photographic companies are exploring the displacing of gelatin with other proteins, and with synthetic polymers, including soy-protein isolate and polyvinyl alcohol; however, any such change appears to be far from commercialization. In the stabilization of ice cream, edible gelatin is losing ground to carboxymethyl cellulose, sodium alginate, and Irish moss, mainly because of the higher cost of the gelatin, which sells at $0.60 to $0.70 a pound. Although some substitution of soy-protein products has been tried in the manufacture of marshmallows, gelatin so far seems to be holding its own. Use of gelatin has also been well maintained in meat packing, where it is used for making luncheon meats and similar products.

Inedible gelatin.—This grade of gelatin contains impurities such as are not allowed in edible and photographic gelatin, although it is made from the same type of raw materials and by similar processes. It is used primarily for sizing paper, textiles, straw hats, and crepe paper. Before World War II, the production in this country ranged between 2.3 and 4.7 million pounds; in the last few years it has approximated 2 million pounds annually. Imports appear to be negligible. Gelatin for warp sizing of viscose-, celanese-, and bember type fabrics sells for about $0.25 to $0.33 per pound. A gelatin of somewhat greater strength used for sizing velvets sells for about $0.40 per pound. Another market for gelatin has been in producing glazed decorative tapes from both paper and fabric.

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