

Cross Linkages in Protein Chemistry

By JOHAN BJORKSTEN

Bjorksten Laboratories for Sponsored Industrial Research, Madison, Wis.

CONTENTS

	<i>Page</i>
I. Introduction.....	343
II. Outline of Types of Industrial Problems Handled by Cross-Linking Reactions.....	345
III. Cross-Linking Processes Indicated in the Patent Literature.....	347
1. General Remarks.....	347
2. Aldehyde Reactions.....	348
3. Reactions Entailing Sulfur Compounds.....	352
4. Reactions Entailing Metals.....	353
5. Quinones.....	355
6. Nitrogen Compounds.....	355
7. Comments on Detergents.....	355
8. Polyhydric Alcohols and Polybasic Acids.....	357
IV. Conclusion.....	357
References (Annotated).....	358

I. INTRODUCTION

Proteins possess not only properties typical to them because of their peculiar chemistry, but also properties common to high polymeric substances of different origin, such as polymers of the vinyl and acrylate types. This article will attempt to coordinate the scattered and diverse data on one of these qualities: the ability to form cross linkages that connect molecules or micelles, thus leading to the formation of larger aggregates. Even a single cross linkage between two large molecules has the immediate result of combining them into a unit having a molecular weight equal to the sum of the molecular weights of the molecules involved; repeated cross linkages multiply the size of molecules that are already extremely large. The immediately observable results are reduced solubility or peptizability, increased resistance to hydrothermal influences; reduced resilience or elasticity, sometimes accompanied by darkening in color, and in extreme cases, brittleness. The darkening may be due to side reactions, often accompanying cross linkage.

In the field of plastics, the tying together of polymer chains by cross linkages has assumed major technical importance, and has accordingly received close theoretical study. Mention may be made briefly of the

fundamental work of Kienle and coworkers on the influence of the functionality of molecules in polymerization. The greater the number of reactive points in the component molecules, the greater is the tendency to form a molecular network leading to high hardness, rigidity and stability in the final product (315, 316). For example, varnishes based on alkyd resins have been greatly improved with the adoption of pentaerythritol as a reactant instead of the conventional glycerol. Pentaerythritol, having four hydroxyl groups, favored the formation of a three-dimensional network of true chemical bonds between the molecules, so that a rigid structure, mechanically and chemically highly resistant, was obtained.

A less extreme form of cross linkage is exemplified in the plastics field by the use of divinyl benzene in low percentages to effect cross linkage between polymer chains in polystyrene. Even a very small percentage of the bifunctional divinyl benzene will greatly improve the rigidity and stability of polystyrenes, and will substantially increase their softening temperature. Numerous other examples in the resin field could be mentioned, but this would digress too far from the subject of this article. Therefore, we may here only briefly refer to articles by Flory and Ferry, respectively, concerning fundamental properties of cross-linked structures (305, 306).

The many reactive groups in protein molecules render them peculiarly susceptible to cross-linking reactions. Aldehydes can form a methylene bridge, or they may react with amino groups linking protein molecules together with the formation of Schiff bases. Dicarboxylic, and particularly disulfonic acids may form cross-linking bridges, presumably by reaction with amino groups. Ions of polyvalent metals effect cross linkages, for example, by reacting with free carboxyl groups in the protein molecule, or by complex formation with amino groups in the protein. The effectiveness of chromium, aluminum, lead, mercury, zinc, copper, and uranyl ions is especially well known in this regard. Quinoid structures are particularly intriguing, since their cross linkages are more stable than those caused by aldehydes, and since structures of this type may also be formed in biochemical reactions, notably in the sterol series.

Inasmuch as potential cross-linking agents are formed normally in the course of metabolism, and others are likely to be formed as intermediates, it can hardly be questioned that the biochemical importance of cross linking will prove substantial, as our knowledge advances.

So far, most of the findings in this field are of an empirical nature, gained from industrial practice. We shall review data obtained mainly from the industrial literature, and shall then briefly touch upon certain biochemical aspects.

In the discussion of industrial data, we shall first very briefly indicate some of the principal purposes that have stimulated industrial experimentation with reactions possibly involving cross linkage of proteins. This outline will be followed by a detailed consideration of the inferences that can be drawn from the patent literature. Inasmuch as the patents are written to support claims, rather than to expound the underlying theory, the picture emerging from the patent references is necessarily very complex, and its interpretation requires a great deal of "reading between the lines."

II. OUTLINE OF TYPES OF INDUSTRIAL PROBLEMS HANDLED BY CROSS-LINKING REACTIONS

In glues and gelatins, great value is placed on certain properties generally associated with high molecular weight, such as high viscosity and high gel strength at great dilutions. Therefore, a strong incentive exists for attempting to impart such characteristics to the lower molecular grades of these proteins.

This is most easily accomplished by means of agents effecting a moderate amount of cross linkage. The addition of even as little as .003% of a chromate or formaldehyde, or somewhat higher percentages of other cross-linking agents, may effect the necessary increase in molecular weight by formation of bridges joining individual molecules.

This bridge formation will follow a random pattern, and the distribution of molecular weight can be fairly accurately anticipated from a probability curve.

These gelatins and related products are used in many types of paper coatings, as well as by the photographic and duplicating industries. Although gelatin is also used in the food industries as a coating for hams and in other meat products, and in the pharmaceutical industry as well, the use of cross-linking agents in foods is, of course, considerably restricted by the requirements of the pure food and drug laws.

In the adhesives industry, an objective is to secure products which can be applied from water solution, but which on standing become increasingly resistant to water. This can be achieved by cross-linking procedures, which progress slowly with time, so as to lead to a progressive insolubilization.

In the textile field, two different aspects require extensive knowledge and application of cross-linking procedures. One aspect is the formation of fibers by precipitation of proteins. The fibers formed are insolubilized by immersion in a passage through baths, which effect extensive cross linkage, to the point of actually rendering the fibers three-dimensionally

bound and completely resistant to any of the common solvents. For this purpose, use is made of aldehydes, metals or tannin as shown below.

In the textile finishing or auxiliary field, the largest single use of proteins is in the sizing of monofilament fibers of rayon, which may be of viscose or acetate type, or of monofilaments of synthetic resin materials. In this application starch, which is customarily employed on short fiber textiles or yarns, is not suitable. The materials principally used are either polyvinyl alcohol or gelatin gels. Here again, increase of molecular weight of gelatin by cross linkage proves economical. Other specialty applications call for certain surface effects such as in the manufacture of chintzes and in creaseproofing, although in this latter field the urea melamine resins have in recent years been most widely used.

Cross linking by active radiation is particularly important in planographic printing. An established procedure here, which is still used by large-scale operators, is the treatment of the printing plates with a solution containing egg white and bichromate. The pH is adjusted, generally with ammonia, to a value near 9, so that the bichromate is converted to chromate. Exposure to radiation brings about a reaction which renders the egg white insoluble and oil receptive on the parts that have been exposed to light. This phototanning process is a chromium cross-linking process, and one which is of great technical importance in photolithography. A recent patent employs blood albumin in this reaction instead of the conventional egg white (260).

In the manufacture of gaskets likewise, where high resistance to a large variety of solvents or oils is required, this is achieved by effecting a very high degree of cross linkage. Synthetic plastics are being increasingly employed for this purpose, but protein treated cross-linked gaskets still retain an important position in this field.

In the paper industry, proteins, particularly casein and soya proteins, are employed largely as suspending agents and protective colloids in the composition of coated paper. Alum is often used here as a cross-linking agent. The surfaces of papers and their printing properties are also considerably influenced by protein materials present.

Finally, in water-type printing inks, particularly for textile printing, cross-linking agents may be similarly employed to impart to proteins present the desired viscosity or flow-out properties.

The same pattern of desired result is evident in applications where the protective colloid or suspension, or auxiliary emulsification properties of the protein are utilized.

Viscosity is not the sole factor to be considered in these cases. The affinity of the surrounding medium to the surface of the suspended

particles, as well as the adjacent orientation, must also be considered. A specific molecular size and arrangement gives the optimum result.

This can be accomplished in two ways: by enzymatically breaking down a high molecular protein substance, such as soya protein; or, by using a cross-linking agent to recombine low molecular proteinaceous materials, or degraded protein fragments, such as low grade glues obtained from the meat packing industry or as products of the partial hydrolysis of leather scrap. In both cases, products having similar surface properties may be arrived at, and in many cases the latter approach gives satisfactory products at a lower cost. Sometimes elimination of surface active properties is desired, as in the use of flour instead of starch after destruction of the foaming properties of proteins present by extreme cross linkage (264).

Under the impetus of the economic inducements indicated, much work has been done and published in the patent literature. In some cases, it may be characterized as by-product utilization, while in other instances, it is directed to obtaining effects which cannot otherwise be realized. Sometimes, the cross-linking effect of ingredients present may not have been evaluated as such by those conducting development work along largely empirical lines, and cross linking may be only one of several effects caused by a certain ingredient.

III. CROSS-LINKING PROCESSES INDICATED IN THE PATENT LITERATURE

1. *General Remarks*

Because of our limited knowledge of protein structures, our knowledge of cross-linking reactions is still in a very early stage. Academically, the methylene bridges and the cross-linking action of formaldehyde are the best explored. In particular, the work of Carpenter and coworkers in measuring the exact distances to be bridged, and calculating the length in Angstrom units of potential links, is a very constructive approach (282). Good summarizing articles are listed in a separate section of the appended bibliography.

A large part of the industrial work on cross linkages has been in the field of leather tanning. The excellent work of Gustavson, Theis, Küntzel, Stiasny, and many others, is presented in another article appearing in the previous volume of *Advances in Protein Chemistry* (310). To avoid duplication, this important work is therefore not touched upon in this article.

Work prior to 1941 has been summarized in previous articles (297, 299).

It remains for us, then, to dwell particularly on references to industrial disclosures of cross-linking reactions reported in the industrial and patent literature within the last five years, with emphasis on findings which suggest that cross linking is involved and may contribute to the results reported.

In many technical reactions, it is uncertain whether or not cross linkage occurs. For example, where a protein is milled with a zinc-oxide pigment, the resultant product will be partially a purely physical mixture, but there will also be cross linkages. This is indicated, for example, by increase in viscosity of compositions so formulated. When dual interpretation is possible, the pertinent reference has been listed in the bibliography.

This literature, on which this presentation largely relies, is a useful guide when its peculiarities are recognized. To obtain claims adequately covering the invention, the inventor is required to enumerate a large number of equivalent or supposedly equivalent substances. For this reason, a patent is likely to list a great number of usable raw materials of which possibly only a few have been tried; the remainder can be regarded as joint guesses of the patentee and his attorney. From the examples in conjunction with the claims, it is usually possible to obtain a fair idea of the essential portions of the disclosure, and to distinguish between what the inventor has actually done and what his attorney has added for legal reasons.

Cross-linking reactions will usually apply quite generally to proteins, or at least will apply equally to different members of the same broad classes, such as prolamines, albumins, and keratins. The distinction between "vegetable" and "animal" proteins often encountered in patents is largely secondary. A listing of specific members of these classes cannot always be taken at face value unless the compound in question has been specifically stated in an example giving detailed process data. Insofar as patents are concerned, this discussion will, therefore, follow the different cross-linking agents employed rather than the specific proteins.

2. *Aldehyde Reactions*

Formaldehyde is by far the most common cross-linking agent. Much of the work in this field is covered by another article in a previous volume (310). Suffice it to say here, that recent spatial studies indicate that methylene bridges are formed between side groups and do not involve the imino groups in the protein chain. From a technical point of view the formaldehyde cross-linked proteins in many regards rank among the least satisfactory. A formaldehyde protein cross linkage is hydro-

thermally rather easily reversible. For example, a protein tanned with anything less than a tremendous excess of formaldehyde will tend to soften and de-tan on long exposure to tropical temperatures and humidities. Furthermore, formaldehyde hardening tends to be a progressive reaction. Embrittlement of formaldehyde-hardened proteins tends to proceed almost indefinitely, even when the formaldehyde originally present constitutes only an extremely small percentage of the mass. This may indicate that more than a simple cross linkage is involved here and that true catalytic effects might be occurring.

Reaction products of formaldehyde resins with proteins are widely represented in patent literature. Either phenol formaldehyde (25, 26, 54, 65, 67, 108, 122, 123, 135, 143, 157, 189, 220, 234) or urea, thiourea, or melamine formaldehyde type resins (1, 6, 7, 8, 14, 15, 17, 19, 20, 22, 25, 27, 29, 30, 31, 33, 34, 48, 50, 52, 62, 63, 65, 87, 91, 101, 106, 130, 143, 151, 157, 180, 199, 209, 240) will react with proteins. In particular, in molding compounds comprising such resins as well as proteins, the aldehyde, which is freed under the influence of the high temperatures used in molding, will react with the proteins so as to cause extensive cross linking.

Many attempts have been made to avoid or reduce the disadvantages of the aldehyde tanned materials. Of interest is, for example, the finding of Atwood (221), that the presence of an acylating anhydride may cause the formaldehyde hardening of a protein to be irreversible hydrothermally.

The higher aldehydes are much milder than the lower molecular aldehydes in their action on proteins. For example, vanillin has no observable cross-linking action. Propyl aldehydes, acetaldehyde, croton aldehyde, and acrolein are quite effective.

Paraldehyde and hexamethylene tetramine are regarded as practical equivalents of formaldehyde. Although rather frequent reference is made to the C2 to C4 aldehydes, it appears that this is done in order to comply with requirements on the completeness of disclosure in patents. It seems doubtful that these aldehydes are used in any case in preference to formaldehyde. Furfural is mentioned (4). These other aldehydes share the weakness of formaldehyde in low hydrothermal stability of the cross linkages produced, and in progressive embrittlement. On the other hand, they do not act as rapidly as formaldehyde.

Higher aldehydes possess efficiency in tanning to a certain degree. Even aldoses are known to cause a progressive hardening of proteins in compositions where they are present in large amounts. It has been reported that the presence of silicates accelerates these hardening reactions, or that a co-action between aldoses and silicates exists in affecting

at least collagens in gelatin gels. These reports have not been confirmed in the literature, and it probably would be important to check them in view of the potential biological significance and the biological ubiquity of both silicates and aldoses. It is not apparent from the published data (268) whether or not silicates enter into the cross-linking function in the Ferretti patent on spinning protein fibers from a silicate containing bath. Cross linkage may also be effected by the use of substances such as active aldehydes which are not themselves cross-linking agents, but which on heating generate such agents. A list of such "aldehydogenic" substances is contained in a patent to Lee and Erikson (95).

Some special applications may be mentioned in which carbonyl groups probably enter into the process. Atwood (187) has used ketene to effect cross linkage in spun protein fibers. In this case, the large surface-volume ratio of fine denier fibers makes possible a good penetration of gaseous cross-linking agents. According to the patentee, the after-yellowing which tends to occur on aldehyde tanning does not take place with this form of hardening. This statement dovetails with the report (221) that acyl anhydrides prevent yellowing of proteins in aldehyde tanning. We note that ketene and acyl anhydrides are both acylating agents. The action of ketene on casein was studied by Schöberl and Krumej from a fundamental standpoint (292). Dihydroxy acetone is also stated to harden proteins (287).

Another special type of aldehyde tanning is the use of cashew shell liquid introduced by Harvey (13). In this instance, it appears possible that the oxidation of unsaturated long-chain fatty acids leads to a scission of the chains with formation of lower aldehydes in the minute quantities necessary for effecting cross linkages.

Dialdehydes such as glyoxal have been used particularly for embalming fluids (H. Jones), and also with glue sizes to increase the wet strength of paper (229).

While most of the references describe the use of substantial quantities of cross-linking agents, it should be borne in mind that even very small amounts of these agents over a period of weeks or months will lead to great changes in the physical characteristics of the proteins in view. Even as little as 0.01% formaldehyde or 0.03% chromium salts may be used industrially for such purposes.

Such low concentrations have been used, for example, in molding compounds utilizing leather scrap (1, 18). Relatively low percentages of the aldehyde type resin will prevent decomposition of a preponderant protein type binder in insulating cork-type compositions (14). This again may be due to a gradual liberation of the aldehyde, or to the

establishment of an equilibrium between aldehyde bound with the protein and with the urea type resin, probably in both cases through methylene bridges.

It is necessary to dispose of leather scrap more rapidly than other materials because the odors which form on storage are exceedingly objectionable.

Many approaches have been made to this problem. One is to decompose the protein, by digestion, usually with calcium hydroxide, and to form hydrolysis products termed "protalbinic" and "lysalbinic" acids. These are then combined with fatty acid chlorides to form surface active agents. Another approach is to make them molding compounds, and to utilize not only the cross-linkage properties, but also the valuable fibrous structure in the leather, to enhance the structural and mechanical properties of the material thus obtained.

In this field we again encounter borderline cases. For example, in the well-known case where glue is used as a stabilizer for an emulsion of a urea-formaldehyde resin for creaseproofing in textiles (33), it is questionable to what extent, if any, the aldehyde combines with the glue to increase its molecular weight by cross linkings. This aspect might profitably be made the subject of a fundamental investigation. The statement by Fiala (283) that formaldehyde treatment lowers protective colloid action is true only when relatively large amounts of formaldehyde have been used.

The degree of protective colloid action depends partly on the length of the chains and partly on their form. There is still tremendous room for detailed exploration on this point. The work done during the war to produce foaming agents for fire extinguishers by controlled hydrolysis of soya proteins uncovered important information on the chain length that yields products with optimum surface activity. The statement that formaldehyde treatment lowers protective colloid action is particularly true for relatively high molecular proteins, or when the cross linkage proceeds far enough to bring the molecular weight of the proteins into a range where solubility becomes distinctly limited. This statement cannot be generalized to embrace all cases. For example, when collagens extracted from bone or pig skin at elevated temperatures are reacted with amounts of aldehyde insufficient to bridge together more than an average of two or three collagen molecules, the resultant products may have higher foaming or film strength properties than the original material.

An interesting modification of a similar principle was introduced by Julian and Oberg (50). These patentees employed the dispersing qualities of urea for protein to effect a uniform dispersion of the protein in

urea. The formaldehyde was added subsequently, and an interesting system of a highly cross-linked protein in a urea formaldehyde resin was thus obtained. A somewhat reminiscent procedure was used in the textile emulsion field by LaPiana *et al.* (87), using mono- or triethanol amine as the protein solubilizer in the presence of urea.

It is obvious that the utilization of aldehyde liberation from resins to cross-link proteins will apply to the general types of vegetable and animal proteins. No attempt is made to specify these types because references to individual proteins in the patents are not believed significant, or even necessarily based on experimental work. However, it is noteworthy that three patents specifically refer to zein in this connection (17, 31, 143). It might have been assumed that the prolamins, with their relative lack of reactive groups could not effectively enter this form of reaction.

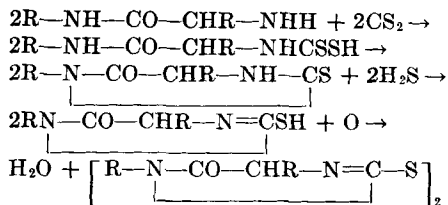
In cross linking, we usually think that the aldehyde used is the hardening agent for a protein. However, the converse is equally true. In a recent patent to d'Alelio, casein is reported as a curing agent for amino triazine formaldehyde resins (91). The exact mechanism might be a simple cementation by casein, hardened by excess or detachable aldehyde or, possibly, it might be an instance where casein is the genuine cross-linking agent that ties together several large polymer micelles of the triazine resin entity.

3. Reactions Entailing Sulfur Compounds

Sulfur occurs as a cross-linking agent in feathers, hair, hoof and other keratinous products. Technical work has been progressing in two diametrically opposed directions. On the one hand, Milton Harris and his coworkers have been striving in their basic work to replace the sulfur cross linkages in wool with ethylene or other bridges less subject to biological or other decomposition. In this connection, mention may be made of the recent report on use of 3:4-isopropylidene-1:2-5:6-dianhydromannitol as a cross-linking agent for animal fibers (302).

On the other hand, numerous other workers have been utilizing the formation of sulfur type bonds in industrial materials.

The most active and certainly the most consistent exponent of this latter trend is Oskar Huppert. Proceeding from the inspirational poetry in his initial publication (288), Huppert has gone on to show the versatility of the sulfur linkage concept in a series of industrial applications. The more recent ones dealing with cross linkages are listed in the bibliography (23, 85, 128, 136, 137, 167). The type of reaction postulated by Huppert (167) is shown by the following equations:



Treatment of proteins, directly or after hydrolysis, with carbon disulfide produces series of compositions of particular interest in coatings and spinning. The sulfurized proteins can be oxidized to form disulfide linkages and even further to sulfonate type surface active agents. The pseudothiohydantoin proteins (136, 137) include prolamin derivatives.

Certain films of this type are highly elastic and are being used in gaskets (79).

The work of A. K. Smith *et al.* on the dispersions of plant proteins with dithionite salts (153) is probably of theoretical interest. There may be a question as to what extent the effects realized are due to the anion and to what extent to the cation in this type compound. The use of xanthate solutions of proteins by Boyer, Atkinson and Robinette for the manufacture of synthetic fibers is noteworthy (166).

A counterpart to the aldehyde stabilization of protein dispersions exists. It is logical that any cross-linking agent will, in a certain optimum concentration, produce improved stability in protein dispersions. The stabilization of zein with aldehydes reported by Brother, Smith and coworkers (171) has its counterpart in the field of sulfur cross linkages. Hagemeyer (172) shows stabilization of zein dispersions by minor percentages of carbon disulfide.

In the field of sulfur type cross linkages, there are again borderline cases in which it is difficult to state whether the effect claimed is due to cross linkages or to some other effect or ingredient.

The work of Cupery and Walker (149, 150) is a case in point. Proteins are reacted with a condensation product of formaldehyde and sulfamic acid. It may be probable that the effect of the sulfamic acid is merely that of moderating the concentration of the formaldehyde, or perhaps of plasticizing the final product. However, the possibility of the sulfamic acid playing a part in the cross linkage in these instances cannot be excluded (256).

4. Reactions Entailing Metals

Cross linkage by the use of chromium salts or chromates forms a very vital part of the leather tanning field and has been exhaustively treated in another article in the preceding volume of this series (310). We shall

therefore refrain here from discussion of the pertinent theory and shall only mention a few fairly recent patents illustrating chromium cross linkage in fields other than leather tanning.

The very high hydrothermal stability of chromate treated protein material renders the chromates particularly suitable for leather tanning and also for protein hardening in the printing and duplicating arts.

An interesting patent of Pierson (68) recites in detail how coating compositions can be made from scrap of chrome tanned leather. In this case, it appears evident that the cross linkage due to the chromate action is an essential link in the process. Interesting water-repellent protein products have been made by the use of Werner type trivalent chromium complexes containing coordinated long chain carboxylic acid groups (174). The chromium in these cases evidently effects a bond between the protein and the long chain fatty radicals, resulting in water repellency. It would be interesting to determine whether a similar principle might be applied to the preparation of surface active agents in analogy with the commercially successful reaction between fatty acid chlorides and protein hydrolyzates.

The chloroprene-acrylonitrile interpolymers, which can be surface tempered to a very high degree of hardness by the use of gaseous chlorine, may employ chrome tanned leather powder in the finish. The role, if any, played by this cross-linked protein filler in the hardening process is not apparent from this du Pont patent (252).

Intriguing, though still not confirmed by other workers, is a report that chromic acid can be employed to *prevent* gelling of casein-urea systems (41).

Use of chromate tanning in the graphic arts has already been mentioned. Chromic anhydride or chromic acid tanning of gelatin has been employed in preparing coatings resistant to penetration of vesicant gases (198).

Salts of zinc, aluminum and earth alkali metals have been used in many instances under conditions where cross linking appears to be at least possible, and often indicated, by the results obtained (46, 77, 93, 98, 119, 139, 145, 154, 156, 169, 178, 197, 203, 208, 239, 253).

Studies on heavy metals other than chromium have been very little reported, if at all, in technical literature. Where the use of copper is reported, it appears to be used more for its fungicidal properties than as a cross-linking agent (190, 266, 275). Claims such as "a polyvalent metal hydroxide" could cover a multitude of metals, but there is very little evidence that recent work published in the patent literature employs metals, other than those stated, on a technical scale. The use of ammonium vanadate may be noteworthy (163).

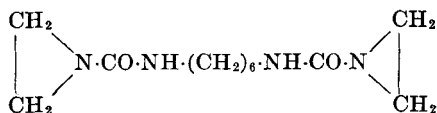
5. Quinones

The quinones are highly important cross-linking agents in many photographic applications, for example. Their reaction products with proteins are hydrothermally much more stable than those of the aldehydes. The sharp pH optimum of the cross linking with many quinones affords an opportunity to carry the reaction to a desired point and then stop it by a pH adjustment, usually toward the acid side. In high concentrations, the quinones impart a yellowish cast to the protein. A relatively high cost is also a drawback in many applications.

6. Nitrogen Compounds

In considering cross-linkage reactions, it may be well to keep in mind that some nitro or nitroso compounds form tautomers likely to be capable of cross-linking reactions, which may be illustrated by a recent patent (237). Further theoretical as well as practical consideration of these possibilities might well prove very fruitful.

An interesting type of protein modifier, which may be a cross-linking agent, is disclosed by Bestian and Bock (130). These substances are employed with casein in adhesives for aluminum or veneers. The structure of the modifiers in question is typified by the following formula:



In view of recent trends in the coating industry, the reaction products of proteins with aryl isocyanates are of particular interest. Of all types of protein cross linking investigated, the isocyanate products impart the highest water resistance to proteins.

It would seem very logical to prepare coating compositions containing isocyanate reaction products of proteins and alkyds in analogy with the aldehyde reaction products with urea protein combinations. Some of the former compounds might be expected to have properties of considerable value in the coatings field. Alkyleneimine-protein-aryl isocyanate reaction products are used as film formers, coatings, and to form textile fibers (40, 42, 43) by Esselmann *et al.*

7. Comments on Detergents

The reaction of proteins with many synthetic detergents is of considerable interest. In particular, it appears that all detergents or substances having a SO_2OH group produce a tanning effect on proteins, which may be due to cross linking through the sulfonate or sulfate group,

rather than to denaturation only, although the phenomena observed could be explained on the basis of denaturation with unfolding of the protein molecule (318, 324). It would be interesting to see a calculation of the spatial relationships involved in this reaction in analogy with the study by Carpenter (282) of the spatial relationships in the case of methylene bridges. In the patent literature of the last five years, many pertinent facts are found which combine to give this impression. Ogden reports naphthalene sulfonic acids as means for increasing the viscosity of protein solutions (37). A similar effect may be ascribed to the butyl naphthalene sulfonic acid, which also functions as a foaming agent in foam adhesives (Menger and Bock, 96). In the fire-fighting compositions of Bagley and Levin (141) the protein is deaminized with nitrite before the sulfonate type wetting agents are added. Favorable results are obtained in this manner probably because the removal of amino groups prevents excessive action on the protein by the sulfonate or sulfate groups of the wetting agents. It may be noted that the corresponding phosphate type wetting agents generally do not have any similar effect on proteins. Sodium alkyl naphthalene sulfonate together with gelatin is employed to emulsify α -fluoromethylacrylonitrile-butadiene combinations (278).

The inclusion of the sulfate type anion active surface agent will improve the stretchability of protein fibers (211).

Diocetyl sodium sulfosuccinate may be an active cross-linking agent. This could account, at least in part, for its selection as a codispersant in protein systems carrying a chromate primer as the disperse phase (239), although other explanations also are plausible, as indicated above.

The polymerized alkyl naphthalene sulfonic acids obviously contain more than one sulfonic group in the molecule, and thus should be particularly active cross-linking agents. This may be a reason for their selection for use with casein in a sheet gasket formulation (Almy, 245).

In recent years considerable work has been done on the use of alkyl sulfonates in gastric ulcer therapy. In this instance, the desired effect is inactivation of pepsin. The mechanism may involve cross linkages (280, 281, 284, 290, 293-295) which might entail mutual affinity of the hydrocarbon portions of detergent ions bound to adjacent protein molecules. Reference should be made here to the proven denaturation effects (279) and to the thorough discussion of interaction between proteins and synthetic detergents by Putnam (324).

An interesting composition is the polyphosphate-urea solution of vegetable proteins disclosed by Horvath (247). This composition, useful in coatings, is soluble in solutions of salts such as aluminum, chromium and iron, which ordinarily cross link proteins instantly to the point of insolubility. The fundamental chemistry of these systems may be a highly interesting area for further study.

8. *Polyhydric Alcohols and Polybasic Acids*

The indication of possible influence of polyhydric alcohols and polybasic acids on collagen gels in hectograph compositions is noteworthy (49). In this case a multiple effect is present which is not easily resolved into its components. In part, the effect may be due to a plasticizing effect from the polybasic alcohol. The polybasic acid may act in forming cross linkages between basic groups in the protein and also will participate in a partial ester formation resulting in long acid-alcohol-acid-alcohol-acid type multiple ester chains, which at any point may be interrupted by reaction with a protein component. The system, briefly hinted at in the patent, might be worthy of theoretical study.

IV. CONCLUSION

The tendency in patents is, generally, to enumerate all conceivable uses which may occur as even remotely possible to the patentee or his attorney. For this reason, statements on the field of utility of an invention are not here incorporated unless apparently supported by experimental data in the examples. A complete systematic listing of all uses cited in the patent literature would be pointless because such a list would include a great majority of the patents under a majority of the headings, and the important uses would be obscured by a large number of secondary or even imaginary applications. Furthermore, the utility of the reactions shown is not of necessity restricted to any particular type of application.

From the vast amount of data actually or possibly related to cross-linking phenomena, it seems apparent that this is a field of protein chemistry where the fundamental work has lagged far behind the possibilities of technical application and technological work dictated by these possibilities. Many phenomena may have been ascribed to denaturation where, in fact, cross linkages play quite an important part. Fundamental study of the nature and processes of cross linkage seems called for.

This appears particularly true in view of the potential importance of cross-linkage phenomena in fundamental biological processes, particularly in aging (298). Knowledge of enzymatic or other means for selectively breaking cross linkages and thereby reducing the molecular weight of cross-linked aggregates, might well prove of major significance in the exploration and control of the changes in protein systems that are associated with progressing age.

With reference to the theory of aging, it may be pertinent to point to the similarities between effects of cross linking on proteins and the changes which proteins undergo in the aging organism. In both cases the changes are the same: reduction of ability to retain bound water, loss of elasticity, brittleness, reduced solubility or peptizability.

If we consider the number of potentially cross-linking substances which are or could be normally formed in metabolism, including the acetaldehyde normally present in the bloodstream (325), it is surprising that the cross linking of body proteins, particularly in arterial walls, does not take place much more rapidly than the observed aging phenomena. We are compelled to conclude that the living organism possesses potent means to counteract progressive cross-linking of proteins.

An inkling as to the nature of these means may be provided by the studies of nitrogen metabolism, which have been performed through depletion studies (333) as well as by means of tracers. "Tagged" nitrogen, introduced by amino acids, spreads rapidly throughout the body, which proves that amino acids and proteins are continually broken down and resynthesized (309, 327, 328).

If cross linkages have formed between two protein molecules, and these are broken down, it is reasonable to assume that they are re-synthesized in their original, non-cross-linked state. Thus the proven continual interplay between anabolic and catabolic processes in the body protein may serve to eliminate cross linkages by breaking down the proteins, and re-synthesizing them in their original state.

This rejuvenation mechanism would fail if, on occasion, cross linkages should form in a steric position, or of a chemical nature that prevents the complete catabolism of the protein of which they form a part. This protein molecule would then be withdrawn from the continual "rejuvenation" cycle of anabolism and catabolism; the structure could be further enlarged and immobilized by additional cross linkages. In this manner, a progressive withdrawal of protein from the life cycle could take place, which should lead to results in all respects similar to those observed in the course of aging of living organisms.

If this process should indeed be a basic cause of natural aging, then there would be hope of its prevention and possible reversal for example by determination of the nature of the causative irreversible cross linkages, and the elimination or control of the causative agent or condition. Should this procedure prove to be impractical, the desired result might be attained by the development or discovery of a specific enzyme system capable of splitting the causative gerogenic cross linkages.

ANNOTATED REFERENCES

It has been attempted to provide with the following annotated reference list a bird's-eye view of progress made in the application field. A brief statement of what appears to be the central thought contained in the reference follows each patent. While such a terse statement is of necessity not complete, it is believed that this treatment will aid the reader in selecting for further study the patents most closely related to his sphere of interests, and will further indicate the vast technological effort now centered in the field of proteins and their cross linkages.

Patent Number	Patentee	Assignee	Concerning
1. Re 22,124	C. Ellis	Ellis-Foster Co.	Urea, and acid, formaldehyde. Tanned leather scrap is mentioned as a filler.
2. 622,455	A. Eichengrün	Farbenfabriken of Elberfeld Co. of N.Y.	Albumen, tannin formaldehyde: "A very valuable remedy for intestinal diseases."
3. 1,035,788	A. Heinemann	—	Synthetic rubber from isoprene by adding protein to isoprene, and then polymerizing.
4. 1,223,745	C. E. Soane	One-half to Usher-Walker, Ltd., London	Gelatinous mass from an amino compound, <i>e.g.</i> , glue, water, glycerin, formaldehyde, formanilin, furfural, hexamethylene tetramine.
5. 1,238,930	E. Munch	Badische Anilin	Polymerized isoprene heated with powdered albumen or glue in nitrogen atmosphere. Rubber type product.
6. 1,672,848	F. Lauter	Rohm & Haas Co.	Aromatic sulfonamide, casein, urea, formaldehyde.
7. 1,725,805	M. Landecker	American Nuplax Co.	Adhesive: Urea, casein, formaldehyde.
8. 1,732,533	L. V. Redman	Bakelite Corp.	Molding mixture from thiourea or urea, casein, paraformaldehyde.
9. 1,732,795	R. P. Dinsmore	Goodyear Tire & Rubber Co.	Two per cent casein is not only an emulsifier for isoprene but is also a catalyst for the hydrocarbon polymerization.
10. 1,901,145	P. C. Christensen	—	Tanned leather scrap hydrolyzed to "leather gum"; compounded with shellac.
11. 1,952,941	K. Ripper	—	Plastic: dicyandiamide, formaldehyde and a protein (<i>e.g.</i> , casein).
12. 1,964,960	G. G. Pierson	Perkins Glue Co.	Adhesive: casein-paraformaldehyde.
13. 2,004,370	M. T. Harvey	Harvel Corp.	Adhesive: Cashew shell liquid with protein.
14. 2,013,698	H. Paschke and C. C. Vogt	Armstrong Cork Co.	Tanned (aldehyde) protein as binder for cork granules.
15. 2,053,850	O. Sturken	Resinox Corp.	Protein plus aldehyde condensation product capable of liberating aldehyde at molding temperatures.

Patent Number	Patentee	Assignee	Concerning
16. 2,067,304	E. Tschunkur and W. Bock	I. G. Farben	Rubberlike butadiene polymerizate, containing, as an alternate possibility, protein emulsifier.
17. 2,075,276	C. Ellis	Ellis-Foster Co.	Fur, feathers, keratin, blood, leather scrap with urea-aldehyde resins. Glycerol halohydrin with zein.
18. 2,075,804	C. Ellis	Ellis-Foster Co.	Leather scrap as filler in molded article from urea, acid, formaldehyde.
19. 2,090,452	M. Landecker	Pfenning-Schumacher Werke G.m.b.H.	Defatted casein as filler in urea-aldehyde resin gives a molding product of good transparency.
20. 2,098,083	A. H. Bowen <i>et al.</i>	I. F. Laucks, Inc.	Adhesive: Sizing protein, zinc chloride, urea-aldehyde.
21. 2,103,293	A. L. Lippert	J. Bancroft & Sons Co.	Chintz: Impregnate cloth with aqueous urea-H-CHO and a coagulatable protein.
22. 2,103,776	E. Geistlich	—	Adhesive, animal glue, urea, aldehyde.
23. 2,112,210	O. Huppert	—	Proteins or their hydrolyzates treated with CS ₂ to form disulfide linkages.
24. 2,114,985	E. B. Schuler	The Glidden Co.	Sealing coating with ammonia casein and boroglyceride to plasticize.
25. 2,121,791	N. S. Frink	Crown Cork & Seal Co., Inc.	Glue gel combined with albumen or casein to form a "gel resin"; also phenol or urea-aldehyde resins, hexamethylene tetramine.
26. 2,121,809	C. E. McManus	Crown Cork & Seal Co., Inc.	Tung oil-glue-gelating binder for cork, hardened with formaldehyde or its polymers.
27. 2,121,844	A. Weisenburg	Crown Cork & Seal Co., Inc.	Composition cork with vehicle of a protein glycerol or glycol plasticizer, aldehyde-urea or -phenol resin.
28. 2,125,776	C. Ellis	Plaskon Division, Libbey-Owens-Ford Glass Co.	Molding compound. Bottle caps <i>etc.</i> from horn-urea-formaldehyde.
29. 2,133,335	W. C. Wilson <i>et al.</i>	Pyroxylin Products Inc.	Coating or adhesive. Mixing urea and formaldehyde in aqueous alkaline solution and dissolving protein in this.

30.	2,159,981	S. Bakonyi	O. Kraus (Prague)	Molding compound. Urea or thiourea-formaldehyde.
31.	2,185,121	R. E. Coleman	The Zein Corp. of America	Heat hardening coating-zein-urea-aldehyde resin.
32.	2,190,776	E. K. Ellingboe and P. L. Salzberg	E. I. du Pont de Nemours & Co., Inc.	NH ₂ -containing solvent soluble substances stabilize chlorine containing plastics.
33.	2,200,931	P. M. Moore	—	Creaseproofing textiles—glue stabilizes urea-formaldehyde-wax-water emulsion.
34.	2,203,501	A. Menger	Plaskon Division, Libbey-Owens-Ford Glass Co.	Adhesive bilateral formaldehyde-urea condensation product, and blood albumin.
35.	2,208,981	S. Horii	—	Protein stencil sheet resin, soya protein, hardener, plasticizer.
36.	2,210,748	W. F. Bernstein	Victor Gasket Co.	Gasket containing about 50 % fiberized leather, about one-third chloroprene; also sulfur, zinc oxide.
37.	2,212,479	F. F. Ogen	Monsanto Chemical Co.	Soluble aromatic sulfonic acid condensation products with carbonyl compounds increase viscosity of proteins.
38.	2,218,255	W. J. Weyerts <i>et al.</i>	Eastman Kodak Co.	Adding 0.3 % polyvinyl phthalate increases 5 % gelatin viscosity 965 %.
39.	2,219,369	K. Memminger	Fahlberg-List A. G. Chem. Fabriken	<i>p</i> -Toluene sulfonamide, protein in alkali dried, then formaldehyde tanned.
40.	2,220,441	P. Esselmann <i>et al.</i>	W. H. Duisberg New York	Fibers, films. A protein, ethylene imine, phenyl isocyanate.
41.	2,223,120	J. J. Murray	—	Protein resin from casein, urea, ammonia with chromium oxide. "The effect of chromium is to prevent gelling. If no chromium oxide is used, the mix slowly gels."
42.	2,231,891	P. Esselmann and J. Dusing	W. H. Duisberg	Fiber of good dye affinity, the fiber being impregnated with protein aryl iso- or thiocyanate-alkylene imine copolymerizate.
43.	2,232,318	P. Esselmann <i>et al.</i>	W. H. Duisberg	Textile finish from ethylene imine plus phenyl iso- or thiocyanate, plus casein.
44.	2,233,885	E. M. Kratz <i>et al.</i>	Marbon Corp.	Sheet triethanol amine caseinate, formaldehyde, chlorinated diphenyl, etc.

Patent Number	Patentee	Assignee	Concerning
45. 2,239,718	E. F. Izard	E. I. du Pont de Nemours & Co., Inc.	Transparent films from polyvinyl alcohols and amino polymers. Other water-soluble vinyl resins disclosed and specific amine-protein compounds listed.
46. 2,243,644	R. J. Myers	Resinous Products & Chemical Co.	Sheets, coatings, etc. Casein made elastic with zinc dodecyl phenoxy acetate, aluminum capryl phenoxy acetate and the like.
47. 2,243,700	R. P. Gutterman	—	Molding composition from scrap leather. Treated with aqueous phenol, hydrolyzed with acid, aldehyde hardened.
48. 2,245,491	A. Menger, E. Bock, and P. Didden	Plaskon Division, Libbey-Owens-Ford Glass Co.	Urea resin condensed in presence of a dispersing agent, <i>e.g.</i> , casein or albuminoid compounds.
49. 2,247,349	W. J. Champion	Ditto, Inc.	Gelatin hectograph gel containing polybasic acid and polyhydric alcohol.
50. 2,249,003	P. L. Julian and E. B. Oberg	The Glidden Co.	Protein dispersed in molten urea, formaldehyde added.
51. 2,253,991	N. Strachovsky	Société Salpa Française	Manufacture of artificial leather by grinding wastes of artificial leather and rubber agglomerant, then working in chlorinated acyclic hydrocarbon solvent (trichloroethylene).
52. 2,256,253	O. Neuss	—	Horn meal swollen in water, urea, formaldehyde added.
53. 2,259,664	C. Schulein	Taccalin Chem. Corp.	Cold sealing compound. Cellulose ester of ether, casein, formaldehyde, volatile solvent.
54. 2,262,422	G. H. Brother <i>et al.</i>	Sec'y of Agriculture, U.S.A.	Soya alpha protein, ethylene glycol, beta stage phenol-H.CHO as molding composition.
55. 2,262,733	W. Nanfeldt	World Bestos Corp.	Friction material containing blood albumin and hexamethylene tetramine.
56. 2,262,770	F. G. LaPiana	Stein Hall & Co. Inc.	Textile size-urea, protein, alkali to disperse, add formaldehyde, acetaldehyde, crotonaldehyde, or their precursors.

57.	2,262,771	F. G. LaPiana	Stein Hall & Co. Inc.	As the preceding, the dispersing alkali being an alkylol amine.
58.	2,264,732	H. M. Weber	Prolamine Products Inc.	Zein dispersed in phenol, then condensed with aldehyde.
59.	2,272,057	H. C. Cheetham	Resinous Products & Chemical Co.	Ammonia-casein as emulsifier for rosin-maleic resin.
60.	2,272,352	K. Ripper	American Cyanamid Co.	Casein cold process. Casein and thiourea or urea stand till swollen, formaldehyde added, room temperature.
61.	2,273,367	L. S. Meyer	Plaskon Division, Libbey-Owens-Ford Glass Co.	Formaldehyde-urea insulating foam. Egg albumen mentioned as foam stabilizer, though gypsum is preferred.
62.	2,279,096	T. Sparre	Borden Co.	Glue: Urea, casein, H·CHO
63.	2,279,743	F. Pollak	—	Moldable masses. Water-free alcoholic methylol urea solution plus casein yields sticky powder. In hot press the first casein is insolubilized, then the methylol urea. Anhydrous conditions essential.
64.	2,280,986	W. C. Toland <i>et al.</i>	W. C. Toland	Planographic printing plates. Water repellent added to bichromated albumin on vinyl plates.
65.	2,281,584	P. L. Julian and E. B. Oberg	The Glidden Co.	Reaction product of an aldehyde and the water-insoluble soya meal residue plus an aldehydeurea or phenol combination.
66.	2,285,183	D. J. Bernardi	Interchemical Corp.	Prolamine inks "set" by water addition.
67.	2,285,193	L. E. Dimond and W. L. Hicks	Carl Marx	Water-soluble slightly acidic degraded protein is reacted with a phenol and an aldehyde.
68.	2,286,038	W. C. Pierson	W. H. Anderson	Chrome tanned leather scrap reclaimed. Detailed claims.
69.	2,288,685	C. M. Croft and Wm. J. Cramer	Celanese Corp. of America	Crepe effects on cellulose derivative fabrics by treating with hot aqueous creping bath containing protein derivative of soya bean.
70.	2,288,751	N. Shane	Celanese Corp. of America	Crepe fabric produced from organic derivative of cellulose by incorporating soya bean protein and then creping bath.

Patent Number	Patentee	Assignee	Concerning
71. 2,289,775	G. DeW. Graves	E. I. du Pont de Nemours & Co., Inc.	Protein-polyamide films age better in outdoor experiment than does either component alone.
72. 2,291,701	H. Dreyfus	Celanese Corporation of America	Spin protein dissolved in alkali polysulfide, into acid bath, liberating sulfur in filaments, then heat.
73. 2,292,624	W. D. Fawthrop	Adhesive Prod. Co.	Adhesive: Blood, silicate, fluoride, alkali.
74. 2,293,805	G. B. Cooke <i>et al.</i>	Crown Cork & Seal Co., Inc.	Phenol-formaldehyde-protein plastic, reaction in presence of propylene glycol, used to bind cork.
75. 2,293,914	W. Nanfeldt	World Bestos Corp.	Friction lining. Blood albumin, aldehyde tanned, as carrier for litharge.
76. 2,293,986	T. Koch	American Enka Corp.	Protein fibers, increasing water resistance by drying and heating directly from aldehyde bath, without intermediate wash.
77. 2,296,108	W. B. Kinney	Borden Co.	Water repellent fabrics, aluminum acetate or formate complex with casein.
78. 2,296,427	W. Daniel <i>et al.</i>	Jasco, Inc.	Polyisobutylene dispersion in water, glue and casein mentioned among other protective colloids.
79. 2,296,464	R. Brown	—	Elastic brownish film for gaskets etc. from soya protein with chlorine, CS ₂ , or formaldehyde, preferably chlorine and CS ₂ .
80. 2,297,206	G. Donagemma	Alien Property Custodian	Textile fibers from alkali protein solution plus phenol.
81. 2,297,397	A. Ferretti	Alien Property Custodian	Textile fibers. Sodium chloride in tanning bath to restrain swelling of fibers.
82. 2,298,127	O. Huppert	The Glidden Co.	Spinning soybean protein disulfide, aldehyde hardening, deaminizing with nitrous acid.
83. 2,298,269	F. C. Atwood	Atlantic Research Associates, Inc.	Coatings-hydrated casein, straight-chain alkylamine and fatty soap aldehyde hardened.
84. 2,304,102	P. L. Julian, A. G. Engstrom, and E. B. Oberg	The Glidden Co.	Soya protein paint; polyhydric alcohols present.
85. 2,309,113	O. Huppert	The Glidden Co.	Artificial fiber of soybean protein disulfide by oxidizing reaction product of soybean protein and

- | | | | |
|----------------|---|--------------------------------------|---|
| 86. 2,309,380 | G. H. Brother and I. L. McKinney | Sec'y of Agriculture, U.S.A. | carbon disulfide, plasticized with soluble polyhydric alcohol.
Protein-aldehyde plasticizer for molding. |
| 87. 2,310,795 | F. G. LaPiana <i>et al.</i> | Stein Hall & Co. | Protein, alkylol amine, urea, liquid hydrocarbon, H-CHO. |
| 88. 2,310,943 | G. L. Dorough <i>et al.</i> | E. I. du Pont de Nemours & Co., Inc. | Polyvinyl acetals are nonmigratory in photo emulsions. |
| 89. 2,312,998 | G. S. de Kadt | Alien Property Custodian | Hardening casein fibers with boiling formaldehyde. |
| 90. 2,315,321 | J. L. Evans and W. A. Hall | E. I. du Pont de Nemours & Co., Inc. | Stop-leak composition: Water, tetrasodiumpyrophosphate, glue, rosin, monoethanolamine, asbestos fiber, sodium silicate, orthophosphoric acid. |
| 91. 2,315,402 | G. F. d'Alelio | General Electric Co. | Curing of aminotriazine-formaldehyde mixture by small amount of protein (casein) and heat. |
| 92. 2,315,708 | A. G. Hovey, T. S. Hodgins, and C. J. Meeske | Reichhold Chemicals, Inc. | Resinous product produced from soybean oil, pentaerythritol, and phthalic anhydride. |
| 93. 2,318,544 | G. I. Thurmond, J. W. Jacokes, and E. Brenner | American Enka Corp. | Viscose-protein mixture for making fibers or films. |
| 94. 2,319,009 | A. McLean | Imperial Chemical Industries, Ltd. | Shaped articles from proteins. |
| 95. 2,320,087 | W. M. Lee and C. R. Erikson | Arabol Mfg. Co. | Adhesives, lists "aldehydogenic" substances. |
| 96. 2,323,831 | A. Menger and E. Bock | Alien Property Custodian | Foam adhesive, casein, wood meal, urea-formaldehyde foaming agent. |
| 97. 2,325,105 | H. A. Bruson <i>et al.</i> | Resinous Products and Chemical Corp. | Plywood adhesive, bithioammeline ether, formaldehyde, acidic catalyst, blood. |
| 98. 2,325,272 | S. Pelierano | Geo. Morrell & Co. | Molded protein articles hardened in zinc salt, then H-CHO. |
| 99. 2,330,504 | G. P. Mack | — | Polyisobutylene dispersions can be used as the only dispersing agent. Borax as peptisizer for casein. |
| 100. 2,332,519 | C. S. Leonardson <i>et al.</i> | Borden Co. | Adhesive: Urea, casein, formaldehyde; pH above 5.5. |
| 101. 2,332,801 | C. S. Leonardson <i>et al.</i> | Borden Co. | Adhesive: Formaldehyde, urea, soya protein. |
| 102. 2,332,802 | C. S. Leonardson <i>et al.</i> | Borden Co. | Adhesive: Urea, formaldehyde, animal protein. |

Patent Number	Patentee	Assignee	Concerning
103. 2,333,526	R. O. Denyes	Tubize Chatillon Corp.	Dispersion action on soya protein of Na or Zn formaldehyde sulfoxylates, yarn treatments.
104. 2,334,107	D. W. Light <i>et al.</i>	American Cyanamid Chem. Corp.	Textile finish: Alkyd composition emulsified with ammonium caseinate.
105. 2,338,151	H. M. Weber	American Maize Products Co.	Printing ink, alkali soap, dispersed corn protein in aqueous medium.
106. 2,338,602	M. O. Schur	Reconstruction Finance Corp.	Wet strength paper; urea, glue, formaldehyde.
107. 2,339,408	J. W. Jacokes, J. J. Schilthuis, and G. I. Thurmond	American Enka Corp.	Heating casein in dry state before dissolving and extruding to fibers, films, etc.
108. 2,340,123	W. R. Heineman	General Electric Co.	Molding compound: Glue plus phenol-formaldehyde varnish.
109. 2,340,866	C. Dangelmajer	Resistoflex Corp.	Compatibility between protein and polyvinyl alcohol improved by addition of formamide or analogues.
110. 2,340,909	D. Traill, R. V. Seddon, and W. Sever	Imperial Chemical Industries, Ltd.	Spinning peanut protein from ammonia solution; aging details.
111. 2,341,413	W. Pense <i>et al.</i>	Alien Property Custodian	Coatings. Protein containing top coat on under coat substance of type: R·NH·CO·N:(CH) ₂ .
112. 2,342,634	F. C. Atwood	Nat'l. Dairy Prod. Corp.	Treating acid coagulable protein fiber with acyl anhydride or ketene.
113. 2,342,739	E. M. Kratz	Kraft Cheese Co.	Lactic acid dispersed casein sheet, insolubilized with formaldehyde, plasticized with formic diethanolamide, embrittlement inhibited by higher acyl or alkyl pyridinium halide 0.03 %.
114. 2,343,011	O. Huppert	—	Adhesive plastic material from zein, ammonium thiocyanate and chloracetic acid.
115. 2,344,267	H. C. Reitz	Sec'y of Agriculture, U.S.A.	Treating gluten with chlorosulfonic acid in presence of pyridine produces highly swellable protein sulfonate.

116.	2,345,345	T. Koch	American Enka Corp.	Adding protein dispersion or hydrolysate to cellulosic filament improves affinity for wool dyes.
117.	2,345,946	S. C. Overbaugh	E. I. du Pont de Nemours & Co., Inc.	Gelatin mentioned as a protective colloid in preparing polyvinyl acetal resins by emulsion polymerization.
118.	2,348,761	O. C. H. Sturken	One half to H. Sturken One half to S. L. Reich	Cold moldable protein plastics: Protein, formaldehyde, kieselguhr.
119.	2,349,235	W. F. Bernstein <i>et al.</i>	Victor Mfg. & Gasket Co.	Gasket from sponge spicules, sulfur, zinc oxide, elastomer components.
120.	2,350,953	W. M. Bain and A. W. Neubauer	The Glidden Co.	Coating for paper. Dispersions made separately of a protein readily soluble in alkali at low pH and of a protein requiring high pH for solution. Both are mixed whereby the latter remains in solution at lower pH than otherwise possible.
121.	2,351,149	Marc de Becker Remy	—	Protein-rubber mixture for extruding threads, etc. Rubber less than 2%.
122.	2,354,479	F. Rosenthal	Univ. of Tennessee Research Corp.	Molding compound: leather scrap, phenol, formaldehyde.
123.	2,355,180	Marc de Becker Remy	—	Lignin reacted first with a protein then with formaldehyde and phenol.
124.	2,356,794	A. L. Peiker	American Cyanamid & Chemical Corp.	Printing pastes for textiles. Urea resin may contain protein as emulsifier.
125.	2,356,795	A. E. Poarch	The Glidden Co.	Coating compositions. Ammonia solution of protein is acted upon by an acid forming gas such as CO ₂ or SO ₂ to displace the ammonia in the solution.
126.	2,357,348	G. P. Netherly <i>et al.</i>	Minnesota Mining & Mfg. Co.	Glue insolubilized with formaldehyde gas mentioned as prior art in sandpaper.
127.	2,357,526	D. W. Light <i>et al.</i>	American Cyanamid & Chemical Corp.	Textile finish. Alkyd emulsion containing casein and sulfonated vegetable oil as emulsifiers.
128.	2,358,807	O. Huppert	—	Fibers or films. Protein disulfides react with primary or secondary amino groups to form a new class of compounds. Hypothetical formulas given.
129.	2,360,081	C. W. Stewart	Corn Products Refining Co.	Zein dispersion containing sulfated stearyl alcohol.

Patent Number	Patentee	Assignee	Concerning
130. 2,360,192	H. Bestian and E. Bock	Alien Property Custodian	Adhesive for aluminum or plywood: Casein plus $(\text{CH}_2)_2\text{N}\cdot\text{CO}\cdot\text{NH}\cdot\text{CH}_2\cdot\text{NH}\cdot\text{CO}\cdot\text{N}:(\text{CH}_2)_2$
131. 2,361,082	N. J. Brown	—	Waterproof tracing cloth-gelatin-bichromate coated sandblasted cylinder is base for casting sheets of cellulose ester.
132. 2,361,277	F. Enderlin <i>et al.</i>	Society of Chemical Industry (Basel)	Textile emulsion of melamine type resin with casein.
133. 2,361,713	O. C. H. Sturken	One-half to S. L. Reich	Zein fibers, diatomite in coagulating bath.
134. 2,363,794	P. L. Julian, E. B. Oberg, and B. T. Malter	The Glidden Co.	Partially hydrolyzed soya protein is formaldehyde treated.
135. 2,363,893	J. B. Monier	—	Phenol-aldehyde type resins are modified with gelatin formate up to butyrate. Inhibits progressive embrittlement.
136. 2,364,034	O. Huppert	—	Rubberlike products from zein and thiocyno acetic acid in phenol, etc.
137. 2,364,035	O. Huppert	—	Soya protein sulfonated by treatment with CS_2 and subsequent oxidation.
138. 2,364,611	L. Auer	Interchemical Corp.	Flattener for printing inks containing casein-abietic acid reaction products, may be hydro generated.
139. 2,364,792	A. L. James	Corn Products Refining Co.	Water resistance of zein increased by addition of polyvalent metal acetates or formates to zein dispersions.
140. 2,364,900	F. A. Hessel and J. B. Rust	Ellis Foster Co.	Acetone resin compositions may contain formaldehyde hardenable nitrogenous bodies.
141. 2,365,619	T. J. Bagley and D. Levin	Hollingshead Corp.	Deaminized protein hydrolyzate as foamer in fire fighting.
142. 2,365,671	L. A. Watt	Monsanto Chemical Co.	Plastic-phenol-formaldehyde with a filler of protein and 50-300% of protein content of a polyvalent metal hydroxide.

143.	2,366,970	J. W. Kroeger <i>et al.</i>	—	Fast printing ink with zein and aldehyde-urea or -phenol resins, glycol solvents.
144.	2,368,466	A. J. Golick <i>et al.</i>	I. F. Laucks, Inc. (Now a division of Monsanto Chemical Co.)	Plywood adhesive of thermosetting resin-blood suspension.
145.	2,368,623	D. J. Tresise and A. F. Ratzler	Pyrene Development Corp.	Foamer from horn meal, hydrolyzed, plus FeCl ₂ as stabilizer.
146.	2,368,767	M. C. Moore	Hercules Powder Co.	Polymerized terpene in casein glue.
147.	2,368,919	E. L. Fritzberg	General Mills, Inc.	Separating proteins by flotation.
148.	2,369,111	I. A. Parfentjev	Lederle Labs. Inc.	Globulin fraction which accelerates blood clotting.
149.	2,369,439	M. E. Cupery	E. I. du Pont de Nemours & Co., Inc.	Proteins reacted with the product of formaldehyde and sulfonic acid, for gels or films.
150.	2,369,503	J. F. Walker	E. I. du Pont de Nemours & Co., Inc.	Method of bringing into contact a protein and formaldehyde derivative of sulfamic acid salt.
151.	2,370,033	H. W. Hall	—	Casein glue waterproofed with urea-formaldehyde.
152.	2,370,057	G. P. Mack	Advance Solvents & Chemical Corp.	Casein borax as emulsifier for polyisobutylene.
153.	2,370,266	A. K. Smith <i>et al.</i>	Sec'y of Agriculture of the U.S.	Paper coatings, protein plus zinc dithionite.
154.	2,370,457	W. S. Gocher, A. J. Jennings, and C. M. Langkammerer	E. I. du Pont de Nemours & Co., Inc.	Chrome tanned leather shaving as rubber filler.
155.	2,370,669	C. B. Joseph	Pilkington Bros. Ltd.	Keratin plus H ₂ S gas or earth alkali sulfides or hydro-sulfides
156.	2,372,622	R. L. Wormell	Courtaulds Ltd.	Hardening protein filaments with acid from formaldehyde and salts.
157.	2,373,401	E. G. King	Armstrong Cork Co.	Insulating material. Plastic foam—volatile dispersing agent used with protein, aldehyde-urea or -phenol resin.
158.	2,374,201	J. H. Highberger <i>et al.</i>	Found. Research Lab. Tanners' Council of U.S.	Gelatin filaments, stretched 1:4, oriented, tanned <i>e.g.</i> , alcoholic tannin solutions.
159.	2,374,667	C. Dangelmajer	—	Proteins plasticized with formamide glycerol, tri-ethanol amine

Patent Number	Patentee	Assignee	Concerning
160. 2,376,133	H. Ford <i>et al.</i>	Ford Motor Co.	Plastic cement from urea-formaldehyde soya meal impregnated with cured phenol-formaldehyde and $\text{NH}_4\text{H}_2\text{PO}_4$.
161. 2,376,595	J. M. Hood	American Cyanamid Co.	Textile emulsion. Acid-type gelatin stated to give best stability of suspension.
162. 2,376,607	J. H. Lum <i>et al.</i>	Monsanto Chemical Co.	"Cocoa bean material" is good filler for aldehyde type plastics.
163. 2,376,908	G. De Niederhausern	Durand & Huguenin S. A. (Basel)	Ammonium vanadate, chromium acetate, sodium formate in protein dispersions.
164. 2,377,237	A. L. James	Corn Products Refining Co.	Zein dispersed directly in water with aid of highly ionized organic long chain compounds such as sulfated oils, etc.
165. 2,377,853	R. A. Boyer, J. Crupi, and W. T. Atkinson	Ford Motor Co.	Soya protein manufacture including a freezing step.
166. 2,377,854	R. A. Boyer, W. T. Atkinson, and C. F. Robinette	Ford Motor Co.	Soya protein spinning solution with xanthate.
167. 2,377,885	O. Huppert	The Glidden Co.	Soya treated with acid pepsin, then alkali, and spun.
168. 2,379,402	H. A. Scholz <i>et al.</i>	U.S. Gypsum Co.	Aqueous protein solution and dehydrated castor oil dispersed.
169. 2,379,812	J. G. Little	Hercules Powder Co.	Rosin ester of polyhydric alcohol and a metal protein complex, for rug backing, etc.
170. 2,379,929	E. R. Rushton	T.V.A.	Calcium metaphosphate as precipitant to separate protein from wastes.
171. 2,380,020	G. H. Brother and A. K. Smith	—	Stable dispersion of partially hydrolyzed soya protein and 4 % excess H-CHO
172. 2,380,429	H. J. Hagemeyer	Eastman Kodak Co.	0.1 % CS_2 stabilizes zein solutions.
173. 2,381,088	R. H. K. Thomson	Imperial Chemical Industries, Ltd.	Stabilized protein solutions.

174.	2,381,752	R. K. Iler	E. I. du Pont de Nemours & Co., Inc.	Water repellent dispersions—proteins plus Werner type trivalent chromium complex with coordinated stearate, etc. groups.
175.	2,383,358	R. L. Wormell	Courtaulds, Ltd.	Hardening of casein fiber, with high specific gravity hardener (H—CHO and salts).
176.	2,383,792	M. T. Harvey	The Harvel Research Corp.	Protein-furfuryl alcohol-formaldehyde. The intermediate product dissolves protein, which on curing remains perfectly dispersed.
177.	2,384,388	R. N. Monte and J. B. Gottfried	Corn Products Refining Co.	Sequence of treatments for preparing whole corn protein.
178.	2,385,240	H. O. Ware	Hercules Powder Co.	Soya protein swelled in H ₂ O and treated with Zn, Cd or Mg salt to improve stability and water repellence.
179.	2,385,674	R. L. Wormell and C. L. Knight	Courtaulds, Ltd.	Hardening casein filaments with formaldehyde and sodium bisulfite.
180.	2,385,679	S. J. Bers	Armstrong Cork Co.	Zein molding powder. Zein, paraformaldehyde and pinewood resin fraction.
181.	2,385,802	J. D. Ferry	Research Corp.	Fibrinogen plastics—thermosetting, rubbery; blood fibrinogen plasticized with glycol.
182.	2,385,803	E. J. Cohn and J. D. Ferry	Research Corp.	Fibrinogen plastics made more rigid by admixture of globulin or albumin.
183.	2,386,744	F. J. Myers	Resinous Products & Chemical Co.	Casein and gelatin usable as protective colloids in dibasic acid-polyhydric alcohol plus amino triazin, carbamide, formaldehyde, etc.
184.	2,388,260	E. A. H. Friedheim	—	Reaction product between pathogenic protein and a diazonium salt capable of liberating a sulfur group.
185.	2,389,183	C. N. Cone	M. & M. Wood Working Co.	Mixing protein and resinous glue.
186.	2,389,292	J. Bjorksten	—	Rhythmic stretching and relaxation while tanning progresses results in improved physical properties of protein.
187.	2,389,605	F. C. Atwood	Atlantic Research Associates, Inc.	For films, hardening, with ketene in gas form, non-yellowing product results.

Patent Number	Patentee	Assignee	Concerning
188. 2,390,073	J. B. Calva	—	For permanent curl, treating hair with aldehyde, buffer, heat.
189. 2,391,368	G. J. Underwood	Hercules Powder Co.	Ammonium caseinate as emulsifier for a glass fiber treating phenolaldehyde resin.
190. 2,391,387	L. Bradshaw <i>et al.</i>	Borden Co.	Casein, copper sulfate and blood as an adhesive.
191. 2,392,582	Geo. S. DeKadt	Alien Property Custodian	Protein fiber hardened with H—CHO, then treated at 40°C. and 100 % RH.
192. 2,393,438	S. M. Weisberg <i>et al.</i>	Sealtest, Inc.	Casein enters into polymer of alkyl acrylate and isoprene, and contributes to principal physical properties.
193. 2,393,753	G. F. d'Alelio <i>et al.</i>	General Electric Co.	Diazinyll carboxy alkyl sulfides as curing agents for aldehyde type resins, including soya protein aldehyde.
194. 2,394,308	T. Kajita and R. Inove	Alien Property Custodian	Sugar or tartaric acid stabilize protein solution (soya) precipitate with copper or zinc salts.
195. 2,394,309	T. Kajita and R. Inove	Alien Property Custodian	Sugar or tartaric acid stabilize protein solution (soya) precipitate with copper or zinc salts.
196. 2,395,502	J. E. Robinson <i>et al.</i>	American Can Co.	Zein solutions with cellulose nitrate as joint liners in cans.
197. 2,396,607	T. H. Rogers, Jr.	Wingfoot Corp.	Casein with polyvinyl acetals, ZnO also mentioned for calking etc.
198. 2,396,923	M. Mendelsohn	—	Poison gas protection—gelatin-chromic anhydride or chromic acid combination.
199. 2,397,194	G. H. Miller	—	Protein flour as filler in urea-formaldehyde resins.
200. 2,397,453	E. White and C. A. Smucker	Owens-Corning Fiber Glass Co.	Mineral wool bonded with furfuryl alcohol dispersion, acid caseinate or gelatin as dispersants.
201. 2,398,307	F. A. Hessel <i>et al.</i>	Ellis Foster Co.	Water-soluble protein, and formaldehyde-acetone resin as hardener.
202. 2,399,055	B. W. Nordlander	General Electric Co.	Zein improves toughness of furfuryl alcohol resin.

203.	2,399,084	F. K. Watson	E. I. du Pont de Nemours & Co., Inc.	Casein, linear carboxylic acid, for spinning fibers. Harden with aluminum salts and formaldehyde.
204.	2,399,748	A. J. Luetngen	P. H. Glatfelter Co.	Lactic casein as protective colloid in paper size. Emphasis on uniform size < 2½ microns.
205.	2,400,377	J. B. Speakman	Perm Ltd.	Keratin fibers treated with bisulfite.
206.	2,401,645	R. K. Iler	E. I. du Pont de Nemours & Co., Inc.	Chromium treatment makes hydrophilic proteins hydrophobic, <i>e.g.</i> , zein.
207.	2,401,685	H. J. Hagemeyer, Jr.	Eastman Kodak Co.	Zein stabilized with ethylene oxide.
208.	2,401,919	C. D. Ender	Hercules Powder Co.	Casein precipitated from skim milk with salt of multivalent metal.
209.	2,402,032	R. M. Fischer	American Cyanamid Co.	Ammonium caseinate in interlining material for garments, with alkyd resin, butylated urea formal- dehyde, or melamine resin.
210.	2,402,128	C. D. Evans	One-half to A. E. Staley Mfg. Co., one-half to American Maize Products Co.	Heating zein with aldehyde 2 hours at 15 lb. steam pressure—coating composition.
211.	2,403,251	F. K. Watson	E. I. du Pont de Nemours & Co., Inc.	Spinning solution of casein plus sodium dodecyl sulfate or the like.
212.	2,403,906	W. J. Burke	E. I. du Pont de Nemours & Co., Inc.	Treatment of keratinous material with monomeric <i>N</i> -(acyl thiomethyl) amide to achieve shrinkproof- ness, susceptibility to permanent set, and sensitivity to alkali.
213.	2,403,937	H. A. Lubs	E. I. du Pont de Nemours & Co., Inc.	Formamidine sulfonic acid for permanent set in hair and shrinkproofing of wool.
214.	2,403,966	J. R. Brown <i>et al.</i>	Standard Oil Co.	Powdered gelatine provides polymerization nuclei in olefin polymerization. Quinone dioxime as "vulcanizer."
215.	2,404,463	M. T. Schmidt	U.S. Gypsum Co.	Aqueous emulsion paint with protein alkyd, and polyethylene glycol fatty ester to prevent streaking and to emulsify.
216.	2,404,665	R. Signer	—	Tanning of casein fibers.
217.	2,405,658	H. Kremer	—	Molding material: Wood and blood superpose phenol-formaldehyde which hardens blood; dry.

Patent Number	Patentee	Assignee	Concerning
218. 2,405,965	R. M. Leekley	E. I. du Pont de Nemours & Co., Inc.	Caseinates mentioned among other emulsifiers for polyamides.
219. 2,406,958	D. M. McQueen	E. I. du Pont de Nemours & Co., Inc.	Dry wool is reacted with styrene, acrylonitrile or the like with iodine as catalyst, to form stable thioether crosslinks.
220. 2,407,225	C. L. Dixon	The Protectoseal Co.	Thermosetting powder: Wheat flour resin, nitrobenzene, calcium oxide, phenol formaldehyde resin, excess formaldehyde.
221. 2,408,026	F. C. Atwood	National Dairy Products Co.	Protein fibers in which the hardening formaldehyde is irreversibly fixed by the use of an acylating anhydride.
222. 2,408,027	F. C. Atwood	National Dairy Products Co.	Protein fibers. Certain amount of free acid in the hardening bath is desirable.
223. 2,409,633	E. L. Kropa	American Cyanamid Co.	Zein a possible filler in alkyd triallyl phosphate resins.
224. 2,410,124	W. L. Morgan	One-half to A. E. Staley Mfg. Products Co. One-half to American Maize Products Co.	2-Ethyl butanoic acid and similar branched chain acids with 4 to 18 C, are remarkable plasticizers for zein.
225. 2,410,792	T. R. Ten Broeck	Wingfoot Corp.	Adhesive to bind synthetic rubbers to nylon cord from casein, Buna S latex, phenol.
226. 2,412,668	A. F. Bandur	Westinghouse Electric Co., Inc.	Magnetic particles bonded together with casein, glycerol phthalate.
227. 2,413,163	O. C. Bacon	E. I. du Pont de Nemours & Co., Inc.	Casein melamineformaldehyde as binder for antimony oxide in flame proofing compounds. Salicyl anilide included, ostensibly as fungicide.
228. 2,413,501	O. Huppert	—	Artificial fibers.
229. 2,414,858	P. B. Davidson	Strathmore Paper Co.	Glue size for paper—dialdehydes used to cross link.
230. 2,419,060	J. Edwardes	Clare L. Brackett	Alkali caseinate as dispersant for inorganic polysulfide-olefin dihalide compositions.
231. 2,419,256	H. W. Dorn	International Minerals and Chemical Corp.	Process for purifying crude glutamic acid obtained from hydrolysis of proteinaceous materials and producing salts thereof.

232.	2,419,816	C. F. Brown	U.S. Rubber Co.	Proteins as dispersants for vinyl copolymerrosin-dimer acid composition.
233.	2,420,736	J. R. Coffman and H. F. Lewis	General Mills, Inc.	Treatment of protein with acids and furfuryl alcohol to produce modified protein of low water absorption properties.
234.	2,424,383	F. E. Calvert	The Drackett Co.	Molding powder: Water soluble phenolic resin at pH 3-6 mixed with alkaline protein solution; dehydrated together.
235.	2,424,813	P. J. Gegner	Pittsburgh Plate Glass Co.	$\frac{1}{4}$ % casein as ingredient in chloroprene coating.
236.	2,425,550	H. P. Lundgren	Sec'y of Agriculture of the U.S.	Protein-colloidal-detergent complexes and from this complex fibrous regenerated protein.
237.	2,426,128	W. W. Trowell	Hercules Powder Co.	Plastic compounds using trimethylol nitromethane, which decomposes to yield aldehyde for cross-linking.
238.	2,426,861	G. Comolli	Sandoz A. G.	Chromium as hardener of protein fibers. Treat fibers with chromic acid, then reducing agent.
239.	2,427,481	G. B. Weible <i>et al.</i>	Lockheed Aircraft	Casein dispersion with Aerosol O T, sulfated oil, zinc chromate primer. Also bentonite and tannic acid.
240.	2,427,503	W. L. Morgan	American Maize Products Co.	Prolamine with aldehyde—urea mixtures which on curing release aldehyde to harden the prolamine.
241.	2,427,504	W. L. Morgan	American Maize Products Co.	Corn gluten with an agent releasing aldehyde at curing temperature.
242.	2,427,532	J. J. Miskel	Nopco Chemical Co.	Casein is a preferred emulsifier for extending rubber latex with an emulsion of cracked gasoline polymer resins; gelatin, albumens, etc. also mentioned.
243.	2,427,760	F. A. Beique	—	Extraction of selective vegetable proteins in acid media.
244.	2,428,603	F. C. Atwood	National Dairy Products Corp.	Hardens textile fibers from protein solution in formaldehyde bath at pH 4-5-7.
245.	2,428,771	R. Almy	Armstrong Cork Co.	Sheet gasket material with casein as a dispersant, and polymerized sodium salts of alkyl naphthalene sulfonic acids. Fibers and heat-curable binders are the mechanical elements.

Patent Number	Patentee	Assignee	Concerning
246. 2,429,214	G. F. Biehn <i>et al.</i>	E. I. du Pont de Nemours & Co., Inc.	Filaments from alkaline prolamine solutions spun into acid formaldehyde baths. Specific ranges given.
247. 2,429,579	A. A. Horvath	Hall Laboratories Inc.	Protein polyphosphates, soluble with aluminum or chromium salts.
248. 2,430,736	D. V. Redfern	Adhesive Products Co.	Cresylic acid-furfural base adhesive, containing as protein materials dried activated sludge or blood or casein.
249. 2,430,828	M. T. Schmidt <i>et al.</i>	U.S. Gypsum Co.	Emulsion paint formulations given, containing casein or vegetable proteins with specific volatile solvents.
250. 2,430,885	J. H. Obey	Chemprotin Products L. Kormendi and B. C. Boeckeler	Gliadin suspension and films, with urea-formaldehyde resins.
251. 2,430,950	H. S. Rothrock	E. I. du Pont de Nemours & Co., Inc.	Zein, casein, soya protein among other modifiers for <i>n</i> -alkoxy methyl polyamide and formaldehyde.
252. 2,431,001	D. J. Sullivan	E. I. du Pont de Nemours & Co., Inc.	Chrome tanned leather used in an interesting chloroprene-acrylonitrile finish, which can be "case hardened" by chlorination.
253. 2,431,119	A. A. Horvath	Hall Laboratories, Inc.	Vegetable protein-polyphosphate-urea solution—may use Al, Cr or Fe salts.
254. 2,431,417	J. H. Obey	Chemprotin Products L. Kormendi and B. C. Boeckeler	Gluten solution in dilute ammoniacal sodium salicylate for recovery purposes.
255. 2,431,738	D. E. Drew	E. I. du Pont de Nemours & Co., Inc.	Shrinkproof film—largely mechanical; protein cross-linking implied incidentally.
256. 2,432,776	L. Lis <i>et al.</i>	Aralac, Inc.	Casein fibers spun into acidic formaldehyde containing suspended solid, to minimize adhesion between fibers.
257. 2,433,029	R. E. Coleman	Time, Inc.	Slow gelling zein solutions, low-boiling alcohol distilled off to adjust water percentage.
258. 2,433,849	E. C. Lathrop and S. I. Aronovsky	Sec'y of Agriculture of the U.S.	Cork substitute resilient gelatin foams.

259. 2,434,688 R. L. Evans — Fibers by dissolving keratin in nonpolar hydroxy alkane thiol, thioglycolate, ethyl mercaptan, thioglycerol react with ethylene chloride to form bithioether cross linkages. Also spun into acid coagulant baths containing peroxide to re-form cystine cross linkages.
260. 2,434,727 C. H. van Dusen, Jr. Addressograph-Multigraph Co. Photosensitive lithographic plate. Blood albumin-bichromate.
261. 2,436,156 R. W. Upson E. I. du Pont de Nemours & Co., Inc. Shaped structures from reduced keratinous proteins. Reduced with thioglycolate, dissolved with ammonia filter, cast or spin. May cross link with alkylene dihalide, dibasic acid halides, dichloroethers, etc. Use also formaldehyde and polyvalent metal.
262. 2,440,193 L. Davis and E. C. Tuukkanen McLaurin-Jones Co. Tape for sealing cartons—protein plus asphalt with glyoxal or chromate and wetting agent.
263. 2,440,516 E. L. Kropa American Cyanamid Co. Films or filaments—casein mixed with a phenol, add monoethanolamine sebacate resin; as precipitant formaldehyde may be used.
264. 2,443,290 J. V. Bauer Stein, Hall & Co., Inc. Flour treated with formaldehyde or its polymers becomes industrial equivalent of starch for many uses; the starch in the flour remains gelatinizable, but the proteins are cross linked to the point where objectionable foaming properties disappear.
265. 2,446,304 C. Roman — Wood chips bonded to form board with urea-aldehyde resin plus rye or wheat flour.
266. 2,446,954 D. V. Redfern Adhesive Products Co. Soya meal, undigested sewage sludge; may use sodium silicate also carbon disulfide or copper sulfate to cross link.
267. 2,446,991 J. R. Alexander *et al.* Wm. Walker & Sons, Ltd. Molding powder from finely divided leather impregnated with melamine-formaldehyde powder.
268. 2,450,889 A. Ferretti Att'y General of U.S. Spinning casein adds silicate to casein dope, coagulating in acid, insolubilizing with formaldehyde. May also add aluminum salt. May introduce carbon disulfide vapor into casein dope.

Patent Number	Patentee	Assignee	Concerning
269. 2,451,186	G. Widmer and W. Hertner	Ciba Ltd.	Glue composition based on Vetch meal with urea-melamine-formaldehyde.
270. 2,452,054	G. Jones <i>et al.</i>	Albi Mfg. Co.	Fire retardant composition which forms a carbonaceous insulating foam when heated. May contain protein and sodium bichromate, or sodium tungstate, or urea-aldehyde resins.
271. 2,453,752	F. G. LaPiana <i>et al.</i>	Stein, Hall & Co., Inc.	Composition to bind pigments to textiles. Lacquered fabrics, casein and vulcanized drying oil, formaldehyde or other aldehyde, oil in water emulsion. Urea and an aldehyde are added to protein in the outer phase.
272. 2,454,730	S. Bakonyi	Att'y General of U.S.	Keratin flour oxidized, then reduced; mixed with an aldehyde containing resin.
273. 2,454,886	R. H. Sapiro	—	Prevention of mist and frost on glass. The composition contains gelatin, nitrocellulose, sodium cholate, and may contain a sulfonated oleic ester.
274. 2,456,269	J. W. Gill	U.S. Gypsum Co.	Plastic joint composition. Animal glue, chromium, source slowly forming alkali, plastic filler.
275. 2,456,727	A. Nikitin	Tennessee Copper Co.	Copper-aluminum salts combined with soya protein to form copper fungicides.
276. 2,456,108	C. L. Baker <i>et al.</i>	Philadelphia Quartz Co.	Adhesive from sodium silicate and colloidal clay with a vegetable protein.
277. 2,457,804	J. O. Bower	—	Suture from human blood plasma residue by dissolving in alkali, extruding into acid formaldehyde.
278. 2,472,811	J. B. Dickey	Eastman Kodak Co.	Example 17 shows gelatin used to emulsify alpha-fluoromethylacrylonitrile, butadiene. Sodium alkyl-naphthalene sulfonate may act as cross linker in addition to surface active properties.

REFERENCES

279. Anson, M. L. (1939). *Science* **90**, 256-7; *J. Gen. Physiol.* **23**, 239-46.
 280. Bucher, G. R. (1941). *Am. J. Physiol.* **132**, 698.
 281. Bull, H. B., and Neurath, H. A. (1937). *J. Biol. Chem.* **118**, 163.
 282. Carpenter, D. C. (1946). *Arch. Biochem.* **9**, 159-64.
 283. Fiala, S. (1943). *Naturwissenschaften* **31**, 370.
 284. Fogelson, S. J., and Schoch, D. E. (1944). *Arch. Internal Med.* **73**, 212-216.
 285. *Forschungsdienst, Sonderheft* **12**, 132-43 (1940).
 286. Franz, E., Riederle, K., Fleishmann, F., and Winkler, W. (1942). *J. prakt. Chem.* [2] **160**, 133-165.
 287. German Patent 720,930, I. G. Farben, "Hardening with dihydroxyacetone."
 288. Huppert, O. (1928). *Konstitution und Konfiguration der Eiweissstoffe*. Deuticke, Leipzig und Wien.
 289. Martinette, M. (1944). *Chemist-Analyst* **33**, 87.
 290. Northrop, J. H. (1923). *J. Gen. Physiol.* **5**, 271.
 291. Olcott, H. S., and Fraenkel-Conrat, H. L. (1946). *Ind. Eng. Chem.* **38**, 104-6.
 292. Schöberl, A., and Krumei, F. (1942). *Die Chemie* **55**, 63-64.
 293. Shoch, D. E., and Fogelson, S. J. (1942). *Quart. Bull. Northwestern Univ. Med. School* **16**, 142.
 294. Varco, R. L., Code, C. F., Walpole, S. H., and Wangensteen, O. H. (1941). *Am. J. Physiol.* **133**, 475-476.
 295. Walpole, S. H., Varco, R. L., Code, C. F., and Wangensteen, O. H. (1940). *Proc. Soc. Exptl. Biol. Med.* **44**, 619.

RECENT SURVEYS

Author	References	Concerning
296. Astbury, W. T.	<i>Colloid Chem.</i> 5 , 529-44 (1944).	Review of Astbury's work on X-ray studies of proteins.
297. Bjorksten, J.	<i>Chem. Inds.</i> June 1941.	Summary of industrial work.
298. Bjorksten, J.	<i>Chem. Inds.</i> Jan. 1942 p. 2, col. 1	Chemistry of duplication, views on relation of cross linkages to aging of proteins.
299. Bjorksten, J.	<i>Chem. Inds.</i> September 1942.	Industrial protein chemistry 1941-42.
300. Bouvet, R.	<i>Fibre and Fabric</i> 99 , No. 3191; 6-9 (1946).	New types of fibers including protein fibers. Highly informed review.
301. Brand, E., and Edsall, J. T.	<i>Ann. Rev. Biochem.</i> 16 , 223-72 (1947).	Broad review largely from biological viewpoint. 252 references.
302. Capp, C. W., and Speakman, J. B.	<i>J. Soc. Dyers Colourists</i> 65 , 402 (1949).	1:2-5:6-dianhydro manni-tol cross links proteins in animal fibers, at 50°C. in acid solution.

Author	References	Concerning
303. Danielsson, K. E.	<i>Svensk Kem. Tids.</i> 60 , 142-51 (1948).	Protein-tannin complexes. Sedimentation constant indicates complex formation at pH 6 to 7, but not at pH 9.4.
304. Felix, K.	<i>Angew. Chem.</i> A60 , 231-6 (1948).	General chemistry and physiology of protein and amino acids.
305. Ferry, J. D.	<i>Advances in Protein Chem.</i> 4 , 1-78 (1948).	Protein gels. Includes discussion of fundamental principles in cross linking.
306. Flory, P. J.	<i>Chem. Revs.</i> 39 , 137-197 (1946).	Fundamental principles of condensation polymerization.
307. Fraenkel-Conrat, H. L., <i>et al.</i>	<i>J. Am. Chem. Soc.</i> 67 , 950-4 (1945).	Reaction of formaldehyde with proteins.
308. Fruton, J. S.	<i>Ann. Rev. Biochem.</i> 16 , 35-54 (1947).	Proteolytic enzymes. Review, nomenclature, protein structure.
309. Gortner, R. A.	Outline of Biochemistry. Wiley, New York, 1949, Chapter 19.	Concise summary of findings and interpretation of protein balance and interchange.
310. Gustavson, K. H.	<i>Advances in Protein Chem.</i> 5 , 353-421 (1949).	Tanning processes.
311. Havinga, E.	<i>Chem. Weekblad</i> 43 , 463-8 (1947).	Development of protein chemistry in recent years.
312. Hewitt, L.	<i>Ann. Rev. Biochem.</i> 12 , 81-92 (1943).	Review on active groups.
313. Julian, P. L.	<i>Bakers Digest</i> 17 , No. 4, 19-23 (1943).	Effect of heat on proteins. A concise article listing and discussing 19 specific effects.
314. Kekwick, R. A., and McFarlane, A. S.	<i>Ann. Rev. Biochem.</i> 12 , 93-114 (1943).	Review on physiochemical aspects.
315. Kienle, R. H.	<i>J. Am. Chem. Soc.</i> 51 , 509 (1929).	Basic work on cross linkings in resins.
316. Kienle, R. H.	<i>Ind. Eng. Chem.</i> 22 , 590 (1930).	Theory of functionality.
317. Krezil, F.	<i>Chem. Ztg.</i> 65 , 377-82 (1947).	Protein polymers. Review.
318. Lundgren, H. P.	<i>Advances in Protein Chem.</i> 5 , 305-351 (1949).	Synthetic fibers made from proteins.
319. Markley, K. S., and Goss, W. H.	Soybean Chemistry and Technology	Soya technology. 684 references.
320. Neurath, H.	<i>Cold Spring Harbor Symposia Quant. Biol.</i> 8 , 80-93 (1940).	Physical and chemical properties of proteins in the light of structure, etc.

Author	References	Concerning
321. Neurath, H.	<i>Chem. Revs.</i> 34 , 157-265 (1944).	Protein denaturation. 418 references.
322. Page, R. O.	<i>J. New Zealand Inst. Chem.</i> 8 , No. 4 (1944).	Proteins and tanning. An address.
323. Pedersen, K. O.	<i>Ann. Rev. Biochem.</i> 17 , 169-200 (1948).	Review of protein work published in 1947.
324. Putnam, F. W.	<i>Advances in Protein Chem.</i> 4 , 80-122 (1948).	Interactions of proteins and synthetic detergents. 152 references.
325. Ri, K.	<i>J. Biochem., Tokyo</i> 32 , 38-50 (1940).	Aldehydes found in the blood stream.
326. Sandor, G.	<i>Bull. soc. chim. biol.</i> 28 , 48-60 (1946).	Denaturation of proteins. Review with 86 references.
327. Schaefer, H. C.	<i>Food in Canada</i> 4 , No. 10, 14-16; Nos. 11, 12, 13, 16 (1944).	"Proteins simplified."
328. Schoenheimer, R.	The Dynamic State of Body Constituents. Harvard Univ. Press, Cambridge, Mass., 1942.	Tracer studies showing dynamic state of body proteins.
329. Schoenheimer, R., and Rittenberg, D.	<i>Physiol. Revs.</i> 20 , 218 (1940).	
330. Smith, A. K.	<i>Soybean Digest</i> 2 , No. 9, 4-5 (1942).	Soybean protein. Properties and uses.
331. Smith, A. K.	<i>Chem. Inds.</i> 58 , 974-7 (1946).	Proteins as industrial raw materials. Broad discussion with useful technical data.
332. Swallen, L. C., and Danehy, J. P.	<i>Colloid Chem.</i> 6 , 1140-8 (1946).	Zein. 53 references.
333. Whipple, G. H.	<i>Am. J. Med. Sci.</i> 203 , 477 (1942).	Dynamic balance in the system of body proteins.