



GELATIN
MANUFACTURERS
INSTITUTE OF
AMERICA

GELATIN HANDBOOK

Written and produced by the members of the GMIA

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Introduction

In the **National Formulary** (1) gelatin is defined as *a product obtained by the partial hydrolysis of collagen derived from the skin, white connective tissue and bones of animals.*

Gelatin derived from an acid-treated precursor is known as Type A and gelatin derived from an alkali-treated process is known as Type B.

In the **Food Chemicals Codex** (1) gelatin is defined as *the product obtained from the acid, alkaline, or enzymatic hydrolysis of collagen, the chief protein component of the of the skin, bones, and connective tissue of animals, including fish and poultry.*

Gelatin CAS#, 9000-70-8, does not occur free in nature, and cannot be recovered from horns, hoofs and other non-collagen containing parts of vertebrate animals. There are no plant sources of gelatin, and there is no chemical relationship between gelatin and other materials referred to as vegetable gelatin, such as seaweed extracts.

The earliest commercial production of gelatin appears to have been in Holland around 1685, followed shortly thereafter in England about 1700. The first commercial production of gelatin in the United States was in Massachusetts in 1808.

Gelatin is an important material, finding application in the food, pharmaceutical and photographic industries as well as diverse technical uses.

Gelatin Production

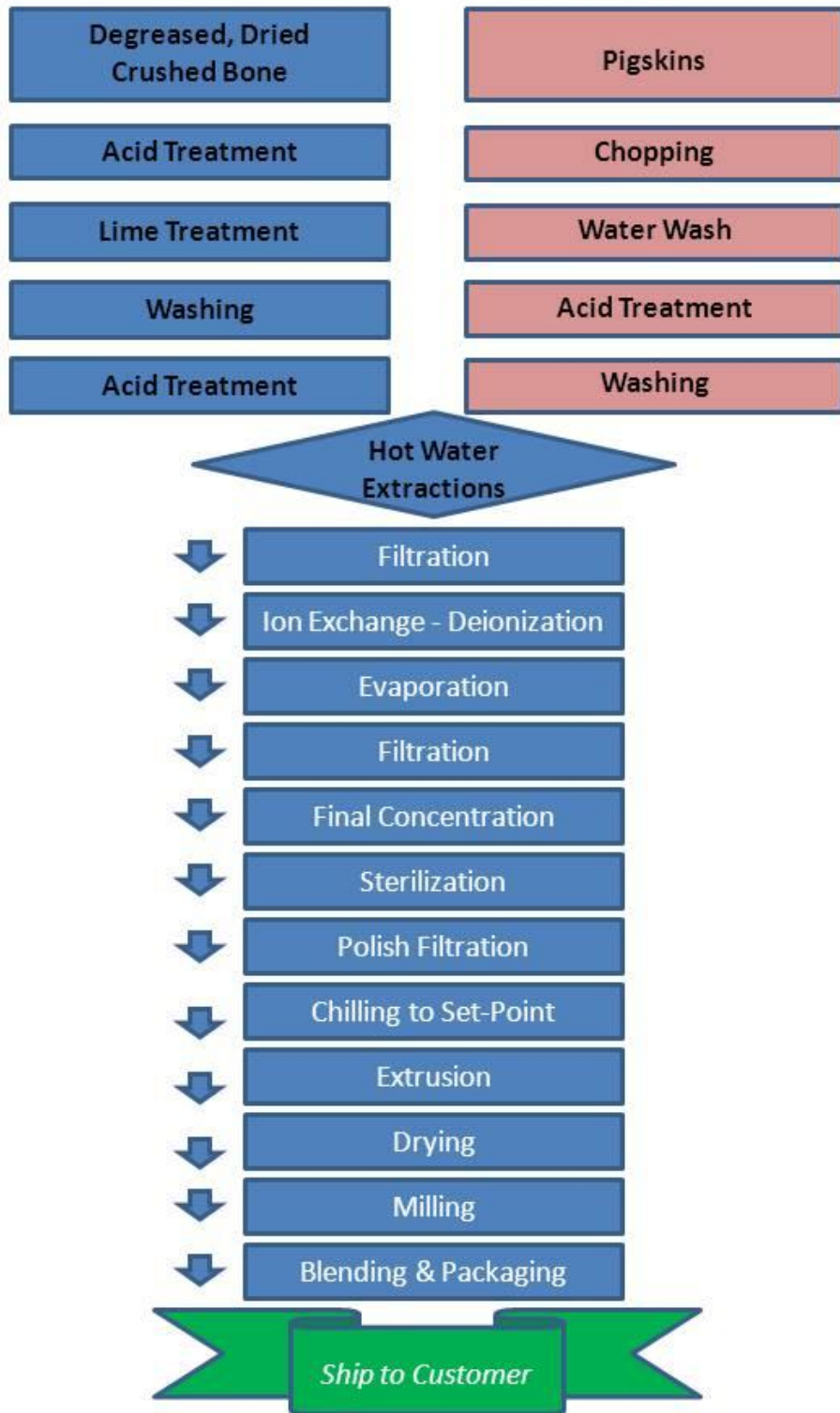
An explanation of the gelatin production process will help in understanding the properties and the characteristics which exist among the several types and grades.

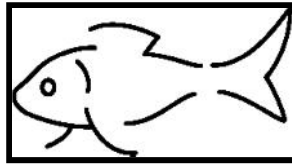
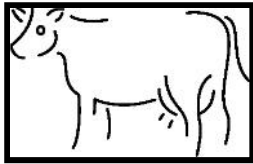
As described in the introduction, gelatin is derived from collagen which is the principal constituent of connective tissues and bones of vertebrate animals (2, 3). Collagen is distinctive in that it contains an unusually high level of the cyclic amino acids proline and hydroxyproline (4). Collagen consists of three helical polypeptide chains wound around each other and connected by intermolecular crosslinks (5, 6).

Gelatin is recovered from collagen by hydrolysis. There are several varieties of gelatin, the composition of which depends on the source of collagen and the hydrolytic treatment used. Typical gelatin production processes are shown in Figure 1 (7).

Throughout the entire process, strict attention is paid to Good Manufacturing Practices and HACCP programs to ensure the purity of the gelatin. The product is tested at various intervals during production and as a finished product to ensure compliance with customer, U.S. and international standards and norms.

GELATIN PRODUCTION PROCESS





The principal raw materials used in

gelatin production are cattle bones, cattle hides, and porkskins. Several alternative sources include poultry and fish. Extraneous substances, such as minerals (in the case of bone), fats and albuminoids (found in skin), are removed by chemical and physical treatment to give purified collagen. These pretreated materials are then hydrolyzed to gelatin which is soluble in hot water.

Gelatin recovered from bone is used primarily for pharmaceutical purposes. The so-called green bone from the slaughter of cattle is cleaned, degreased, dried, sorted, and crushed to a particle size of about 1-2 cm. The pieces of bone are then treated with dilute hydrochloric acid to remove mineral salts. The resulting sponge-like material is called ossein. From this point on in the manufacture of Type B gelatin, both cattle hides and ossein receive similar treatment.

Cattle hides are available from trimming operations in leather production. The hide pieces are usually dehaired chemically with a lime/sulfide solution followed by a mechanical loosening.

For the production of Type B gelatin, both ossein and cattle hide pieces are subjected to lengthy treatment with an alkali (usually lime) and water at ambient temperature. Depending on previous treatment, the nature of the material, the size of the pieces, and the exact temperature, liming takes 5-20 weeks, usually 8-12. The process is controlled by the degree of alkalinity of the lime liquor as determined by titration with acid, or by making test extractions.

Ossein usually requires more liming time than cattle hides. Additional lime is added to maintain an excess, thereby compensating for any consumed. During liming some deamination of the collagen occurs, with evolution of ammonia. After conditioning, the raw material is thoroughly washed with cold water to remove excess lime; the pH adjusted with acid; and the product extracted with hot water to recover the soluble gelatin.

Porkskin is a significant raw material source for production of edible gelatin in the United States. The short time required for pre-treatment prior to extraction, and the minimization of wastewater generated are important economic factors in the manufacture of gelatin from this raw material. Supplied as either fresh or frozen, porkskins come from slaughter houses and meat processing plants already trimmed of fat, flesh and hair. Porkskins are usually dehaired by scalding with a hot dilute caustic soda solution.

When porkskins are utilized for production of Type A gelatin they are washed with cold water and then soaked in cold dilute mineral acid for several hours until maximum swelling has occurred. Hydrochloric acid and sulfuric acid are most commonly employed. The remaining acid is then drained off and the material is again washed several times with cold water. The porkskins are then ready for extraction with hot water.

The pH, time, temperature, and number of extractions varies from processor to processor depending on product needs, type of equipment employed, timing of operations, and economics. Extraction procedures are closely controlled in the manufacture of both Type A and Type B gelatin since they influence both quality and quantity. Although continuous extraction is used by some processors, most methods still employ discrete batch fractions. Extraction is normally carried out in stainless steel vessels equipped with provisions for heating and temperature control.

The number of extractions varies, 3-6 is typical. The first extraction generally takes place at 50-60° C, subsequent extractions being made with successive increases in temperature of 5-10° C. The final extraction is carried out close to the boiling point. Extracts are kept separate, analyzed, and subsequently blended to meet various customer specifications.

The initial extraction usually provides a superior product, compared with subsequent extractions. Earlier extractions have higher molecular weights, higher viscosity, higher gel strength, and lighter color. The later extractions are made at increasingly higher temperatures; the resulting product has lower molecular weight, lower gel strength, and darker color.



The dilute gelatin solutions from the various hot water extractions are filtered, deionized, and concentrated by crossflow membrane filtration and/or vacuum evaporation. The gelatin solution is then chilled and either cut into ribbons or extruded as noodles, and the gelled material is deposited as a bed onto an endless, open weave, stainless steel belt.

The belt is passed through a drying chamber, which is divided into zones in each of which the temperature and humidity of the drying air is accurately controlled. Typical temperatures range from about 30° C in the initial zone up to about 70° C in the final zone. The air is

usually conditioned by filtration, dehumidification and tempering. Drying involves progressive increases in air temperature, often with exhaustion of moist air and replenishment with conditioned air. Drying time is 1-5 hours, depending on the quality and concentration of the material and the exact conditions employed. The rate of drying is carefully controlled to avoid melting and case hardening. The gelatin leaves the dryer with a moisture content of approximately 10%. The dried bed is then broken into pieces that are ground to the required particle size. Dried gelatin is tested for quality and gel strength according to standard methods developed by the Gelatin Manufacturers Institute of America (8).

Although gelatins are sometimes referred to as edible, pharmaceutical, photographic or technical, these terms refer only to their uses, and not to the methods of manufacture.

PHYSICAL AND CHEMICAL PROPERTIES

Gelatin is nearly tasteless and odorless (FCC). It is a vitreous, brittle solid faintly yellow in color. Gelatin contains 8-13% moisture and has a relative density of 1.3-1.4. When gelatin granules are soaked in cold water they hydrate into discrete, swollen particles. On being warmed, these swollen particles dissolve to form a solution. This method of preparing gelatin solutions is preferred, especially where high concentrations are desired. Behavior of gelatin solutions is influenced by temperature, pH, ash content, method of manufacture, thermal history and concentration.

Gelatin is soluble in aqueous solutions of polyhydric alcohols such as glycerol and propylene glycol. Examples of highly polar, hydrogen-bonding, organic solvents in which gelatin will dissolve are acetic acid, trifluoroethanol, and formamide. Gelatin is insoluble in less polar organic solvents such as benzene, acetone, primary alcohols and dimethylformamide (9).

Gelatin stored in air-tight containers at room temperature remains unchanged for long periods of time. When dry gelatin is heated above 45° C in air at relatively high humidity (above 60% RH) it gradually loses its ability to swell and dissolve (10).

Sterile solutions of gelatin when stored cold are stable indefinitely; but at elevated temperatures the solutions are susceptible to hydrolysis.

Two of gelatin's most useful properties, gel strength and viscosity, are gradually weakened on prolonged heating in solution above approximately 40° C. Degradation may also be brought about by extremes of pH and by proteolytic enzymes including those which may result from the presence of microorganisms (11-14).

Collagen may be considered an anhydride of gelatin. The hydrolytic conversion of collagen to gelatin yields molecules of varying mass: each is a fragment of the collagen chain from which it was cleaved. Therefore, gelatin is not a single chemical entity, but a mixture of fractions composed entirely of amino acids joined by peptide linkages to form polymers varying in molecular mass from 15,000 to 400,000 (15-21).

Gelatin, in terms of basic elements is composed of 50.5% carbon, 6.8% hydrogen, 17% nitrogen and 25.2% oxygen (22).

Since it is derived from collagen, gelatin is properly classified as a derived protein. It gives typical protein reactions and is hydrolyzed by most proteolytic enzymes to yield its peptide or amino acid components (12).

The various amino acids obtainable from some gelatins by complete hydrolysis, in grams per 100 grams of dry gelatin, are listed in Table 1 (23-27).

TABLE 1. AMINO ACID COMPOSITION OF GELATINS

	Type A (Porkskin)		Type B (Calf Skin)		Type B (Bone)	
Alanine	8.6	10.7	9.3	11.0	10.1	14.2
Arginine	8.3	9.1	8.55	8.8	5.0	9.0
Aspartic Acid	6.2	6.7	6.6	6.9	4.6	6.7
Cystine	0.1		Trace		Trace	
Glutamic Acid	11.3	11.7	11.1	11.4	8.5	11.6
Glycine	26.4	30.5	26.9	27.5	24.5	28.8
Histidine	0.9	1.0	0.74	0.8	0.4	0.7
Hydroxylysine	1.0		0.91	1.2	0.7	0.9
Hydroxyproline	13.5		14.0	14.5	11.9	13.4
Isoleucine	1.4		1.7	1.8	1.3	1.5
Leucine	3.1	3.3	3.1	3.4	2.8	3.5
Lysine	4.1	5.2	4.5	4.6	2.1	4.4
Methionine	0.8	0.9	0.8	0.9	0.0	0.6
Phenylalanine	2.1	2.6	2.2	2.5	1.3	2.5
Proline	16.2	18.0	14.8	16.4	13.5	15.5
Serine	2.9	4.1	3.2	4.2	3.4	3.8
Threonine	2.2		2.2		2.0	2.4
Tyrosine	0.4	0.9	0.2	1.0	0.0	0.2
Valine	2.5	2.8	2.6	3.4	2.4	3.0

Amphoteric Properties – Gelatin in solution is amphoteric, capable of acting either as an acid or as a base. In acidic solutions gelatin is positively charged and migrates as a cation in an electric field. In alkaline solutions gelatin is negatively charged and migrates as an anion. The pH of the intermediate point, where the net charge is zero and no movement occurs, is known as the Isoelectric Point (IEP) (28). Type A gelatin has a broad isoelectric range between pH 7 and 9. Type B has a narrower isoelectric range between pH 4.7 and 5.4 (29-32).

Gelatin in solution containing no non-colloidal ions other than H⁺ and OH⁻ is known as isoionic gelatin. The pH of this solution is known as the Isoionic Point (pI). These solutions may be prepared by the use of ion exchange resins.

Chemical Derivatives – Gelatin may be chemically treated to bring about significant changes in its physical and chemical properties. These changes are the result of structural modifications and/or chemical reactions. Typical reactions include acylation, esterification, deamination, cross-linking and polymerization, as well as simple reactions with acids and bases (33-37).

Gel Strength – The formation of thermoreversible gels in water is one of gelatin's most important properties. When an aqueous solution of gelatin with a concentration greater than approximately 0.5% is cooled to approximately 35-40°C it first increases in viscosity, and then later forms a gel. The rigidity or strength of the gel depends upon gelatin concentration, the intrinsic strength of the gelatin, pH, temperature, and the presence of any additives. The intrinsic strength of gelatin is a function of both structure and molecular mass.

The first step in gelation is the formation of locally ordered regions caused by the partial random return (renaturation) of gelatin to collagen-like helices (collagen fold). Next, a continuous fibrillar three-dimensional network of fringed micelles forms throughout the system probably due to non-specific bond formation between the more ordered segments of the chains. Hydrophobic, hydrogen, and electrostatic bonds may be involved in the crossbonding. Since these bonds are disrupted on heating, the gel is thermoreversible. Formation of the crossbonds is the slowest part of the process, so that under ideal conditions the strength of the gel increases with time as more crossbonds are formed. The total effect is a time-dependent increase in average molecular mass and in order (38,39).

The gel forming quality of gelatin is a significant physical quality parameter. The measurement of this property is very important from both a control standpoint and as an indication of the amount of gelatin required by a particular application. Figures 2 – 6 illustrate the behavior of gelatin gels as influenced by the effects of time, concentration, pH and temperature (40).

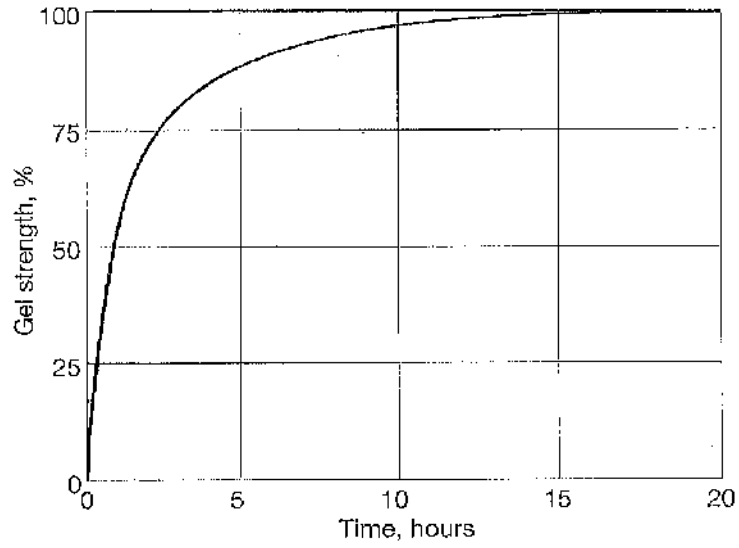


Figure 2. Increase in gel strength of a 6 2/3% gel at 10°C as a function of time, expressed as percent of final gel strength.

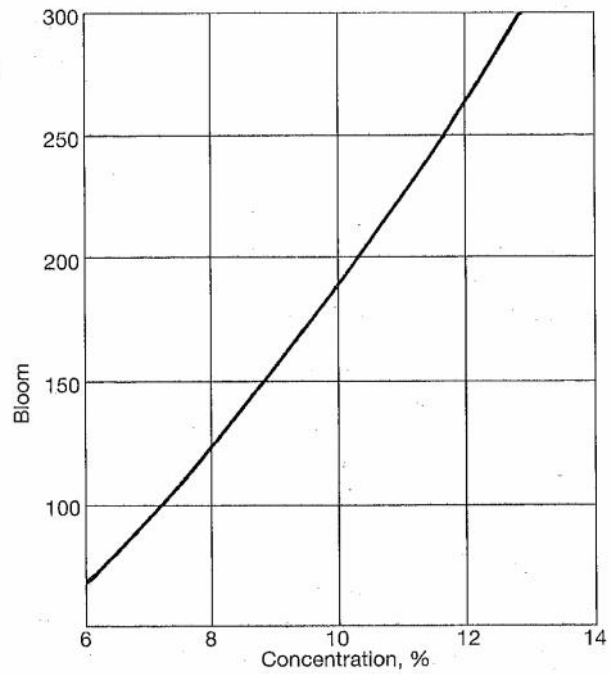


Figure 3. Gel strength as a function of gelatin concentration, at 10°C.

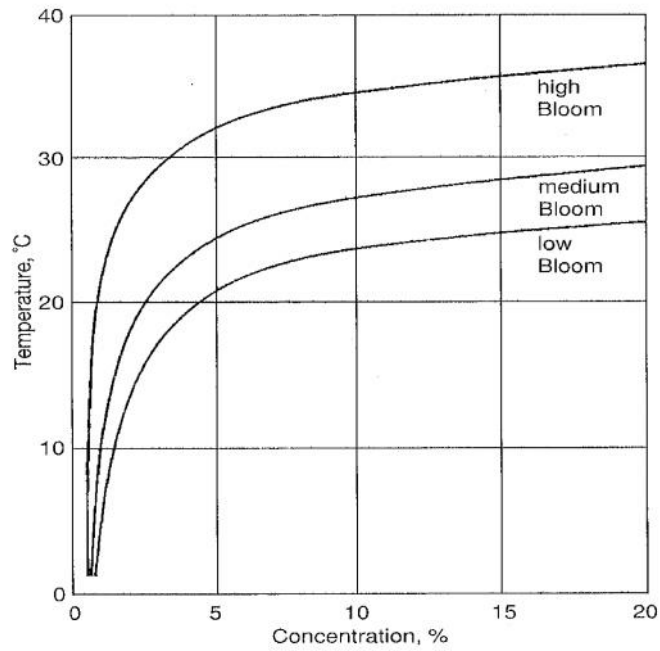


Figure 4. Variation in melting point as related to temperature and gel concentration for low, medium and high Bloom gelatins.

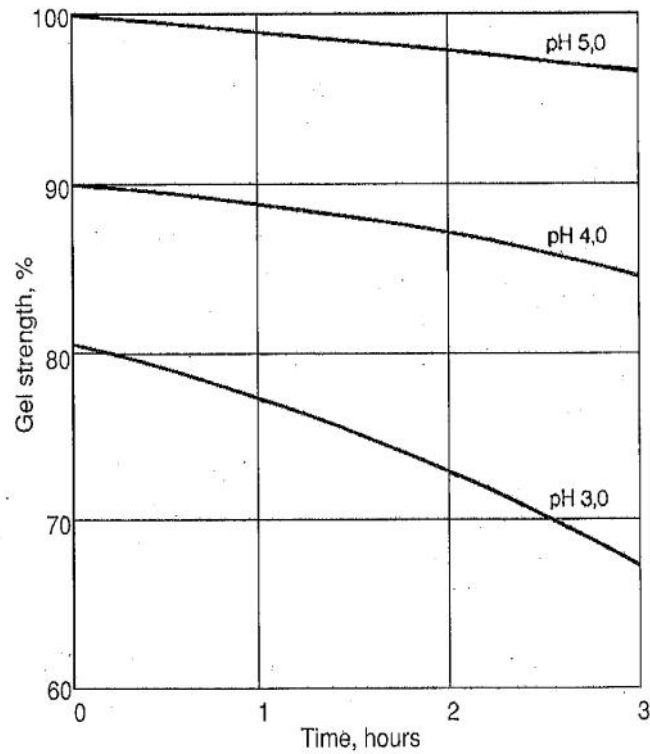


Figure 5. Loss of gel strength at 60°C as a function of pH and time.

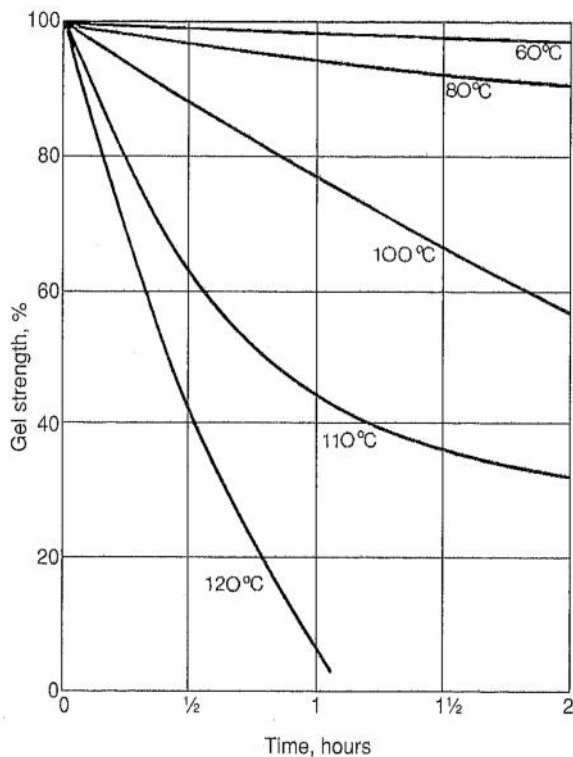


Figure 6. Loss of gel strength at pH 5.5 as related to temperature and time.

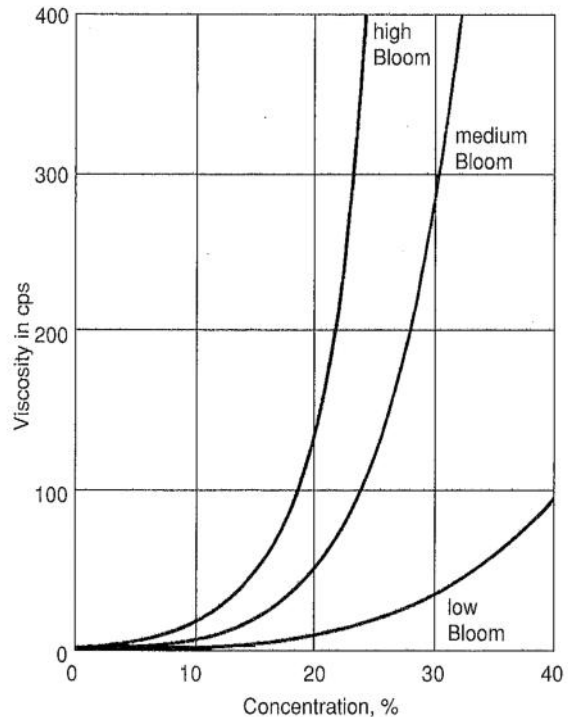


Figure 7. Viscosity behavior as a function of gelatin concentration at 60°C.

Viscosity - The established method for the determination of viscosity involves efflux time measurement of 100ml of a standard test solution from a calibrated pipette viscometer (8). In certain cases viscosity is determined at concentrations at which the gelatin is to be used (41).

Molecular weight distribution appears to play a more important role in the effect on viscosity than it does on gel strength. Some gelatins of higher gel strength may have lower viscosities than gelatins of lower gel strength.

The viscosity of gelatin solutions increases with increasing gelatin concentration and with decreasing temperature; viscosity is at a minimum at the isoionic point.

Figure 7 illustrates viscosity behavior for low, medium and high bloom gelatins, as a function of concentration, at 60°C. (40)

Protective Colloidal Action - Gelatin is a typical hydrophilic colloid capable of stabilizing a variety of hydrophobic materials. The efficiency of gelatin as a protective colloid is demonstrated by its Zsigmondy gold number which is the lowest of any colloid (42,43). This property is especially valuable to the photographic and electroplating industries.

Coacervation - A phenomenon associated with colloids wherein dispersed particles separate from solution to form a second liquid phase is coacervation. Extensive coacervation studies have been conducted with gelatin (44,45).

A common application of coacervation is the use of gelatin and gum Arabic to produce oil-containing microcapsules for carbonless paper manufacture (46-48). Coacervation is also useful in the photographic industry (49,50).

Color - The color of gelatin depends on the nature of the raw material used and whether the gelatin represents a first, second or further extraction. Porkskin gelatins usually have less color than those made from bone or hide. Generally speaking, color does not influence the properties of gelatin or reduce its usefulness.

Turbidity – Turbidity may be due to insoluble or foreign matter in the form of emulsions or dispersions which have become stabilized due to the protective colloidal action of the gelatin, or to an isoelectric haze. This haze is at a maximum at the isoelectric point in approximately 2% solutions. At higher concentrations or different pHs the haze will be appreciably less.

Ash – The ash content of gelatin varies with the type of raw material and the method of processing. Porkskin gelatins contain small amounts of chlorides or sulfates. Ossein and hide gelatins contain primarily calcium salts of those acids which are used in the neutralization after liming. Ion exchange treatment may be used for demineralizing or de-ashing of gelatins.



BACTERIA & PRESERVATIVES

Gelatin is an excellent growth medium for bacteria. Therefore, strict sanitary practices must be followed during manufacture in order to assure a clean, wholesome product.

Food grade gelatins typically contain less than 3,000 bacteria per gram, with no pathogens present. Pharmaceutical gelatins are limited to aerobic plate counts of 1000 per gram. The National Formulary and the Food Chemical Codex monograph on gelatin both require that *Salmonella* species and *Escherichia coli* be absent.

The gelatin molecule is not only thermally labile, but also can be degraded rather quickly by certain bacteria, diminishing both gel strength and viscosity. Consequently, care must be taken to prevent contamination during use.

As a dry powder, gelatin is very stable, and can be stored in air-tight containers for years with no loss in quality. Gelatin in solution, or soaking in water, should be left in this state only if kept very cold, or hot enough to destroy or inhibit bacterial growth.

The nature of the organisms which grow in gelatin solutions and gels depends upon a number of factors. The pH has a most important influence. At pH values less than 4, bacterial growth is suppressed, while yeasts and molds grow abundantly. Above pH 5, proteolytic bacteria can become active.

Degradation of gelatin solutions and gels by bacteria, yeasts, and molds may be inhibited by the use of preservatives. The selection of the preservative depends upon whether the product application is edible, topical, or technical. Gelatin gels generally require a greater concentration of preservative than do dilute gelatin solutions. The addition of other nutrients to the gelatin may also increase the amount of preservative required.

GELATIN TESTING

Through the combined efforts of the technical staffs of the member companies, the Gelatin Manufacturers Institute of America has published a detailed volume which describes the methods of sampling and testing of gelatins (8). In

addition, the analytical procedures are continually reviewed and updated via collaborative testing. This cooperative testing has led to significant improvements in the testing precision and accuracy of gelatin results.



Gel strength and viscosity are the two most important measurements used to assess the grade and quality of a gelatin. The gel strength is determined using a texture analyzer (52). A pipet viscometer is used to determine viscosity. Both tests are based on a standard 6.67% test solution. Gelatin weights for standard tests are made as is, without moisture correction.

The procedure for gel strength determination is summarized as follows:

A water solution consisting of 6.67% gelatin (7.50 +/- 0.1g gelatin and 105.0 +/- 0.2g deionized water, melted at 60-65°C) is carefully prepared in a specified 150 ml, wide-mouth, glass bottle, which is then placed in a chilled water bath and held at 10 +/- 0.1°C for 17 +/- 1 hours. After chilling, the rigidity of the gel is measured as the force, in grams, required to

impres a standard 0.500 +/- 0.001 inch diameter plunger to a depth of 4 millimeters into the surface of the gel. This weight is referred to as the gel strength, or Bloom rating, of the gelatin. The greater the force required, the higher the strength of the gel. Commercial gelatins range from 50 to 300 Bloom grams.



In 1989, Texture Technologies of Scarsdale, New York, released their newest texture analyzer, the TA.XT2. The TA.XT2 has improved precision and accuracy, computer interfacing, and greatly enhanced programmability. Other texture analyzers available for testing bloom strength include the Boucher electronic jelly tester, LFRA Texture Analyser, Brookfield CT3.

In practice, the viscosity of gelatin is usually measured on the very same sample used for gel strength determination. The 6.67% test solution is carefully brought to 60°C whereupon 100 ml is introduced into a calibrated capillary pipet. The efflux time, in seconds, is recorded, and later converted to millipoise based on the relationship established at time of calibration. Each individual gelatin viscosity pipet is calibrated with oils traceable to the National Institute for Standards and Technology.

Other analytical procedures in the gelatin Standard Methods manual include the determination of:

Test	Methodology
Identity	Hydroxyproline analysis and gel reversibility testing.
Moisture	Loss in weight on drying
pH	Potentiometric
Granulation	Standard sieve analysis
Ash	Residue on ignition
Heavy Metals	Wet chemistry
Fluoride	Colorimetry
Arsenic	Colorimetry
Clarity	Light transmittance at 640nm

EDIBLE GELATINS

Commercial gelatins vary from 50-300 Bloom grams and, except for specialty items, are free of added colors, flavors, preservatives, and chemical additives. Gelatin is a generally recognized as safe (GRAS) food ingredient.

Typical specifications for edible gelatins are:

	Type A		Type B	
pH	3.8	5.5	5	7.5
Isoelectric Point	7	9	4.7	5.4
Gel Strength (Bloom)	50	300	50	300
Viscosity (mps)	15	75	20	75
Ash	0.3	2	0.5	2

Two of gelatin's most desirable properties are its melt-in-the-mouth characteristics and its ability to form thermoreversible gels. In addition, gelatin is relatively unaffected by ionic strength and is stable over a broad pH range. Gelatin is preferred in many applications for its clarity and bland flavor.

Table 2 lists several food categories which utilize gelatin, and recommended use levels and Blooms.

TABLE 2. GELATIN AS A FOOD INGREDIENT

	Use Level		Gelatin Bloom	
Dairy Products	0.2	1.0%	150	250
Frozen Foods	0.1	0.5%	225	250
Gelatin Desserts	7	9%	175	275
Confectionery				
Gummy Bears	7	9%	200	250
Marshmallows	1.7	2.5%	225	275
Circus Peanuts	2	2.5%	225	250
Lozenges	0.5	1.0%	50	100
Wafers	0.5	1.0%	50	100
Bakery Fillings & Icings	1	2.0%	225	250
Meat Products	1	5%	175	275
Wine, Beer, Juices	0.002	.015%	100	200

Confectionary – Confections are typically made from a base of sugar, corn syrup and water. To this base is added flavor, color and texture modifiers. Gelatin is widely used in confections because it foams, gels, or solidifies into a piece that dissolves slowly or melts in the mouth.



Confections such as gummy bears contain a relatively high percentage of gelatin. These candies dissolve more slowly thus lengthening the enjoyment of the candy while smoothing the flavor.

Gelatin is used in whipped confections such as marshmallows where it serves to lower the surface tension of the syrup, stabilize the foam thru increased viscosity, set the foam via gelation, and prevent sugar crystallization.

Gelatin is used in foamed confections at a 2-7% level, depending upon the desired texture. Gummy foams use about 7% of a 175 Bloom gelatin. Marshmallow producers generally use 2.5% of a 250 Bloom Type A gelatin.

Gelatin Desserts – Gelatin desserts can be traced back to 1845 when a U.S. patent was issued use for “portable gelatin” for use in desserts. Gelatin desserts remain popular: the current U.S. market for gelatin desserts exceeds 100 million pounds annually.



Today’s consumers are concerned with caloric intake. Regular gelatin desserts are easy to prepare, pleasant tasting, nutritious, available in a variety of flavors, and contain only 80 calories per half-cup serving. Sugar-free versions are a mere eight calories per serving.

A typical gelatin dessert formula would be:

Sucrose	86.5%
Gelatin (250 Bloom)	9.0%
Fumaric Acid	2.5%
Sodium Citrate	1.2%
Salt	Optional
Flavor	As needed
Color	As needed

The buffer salts are used to maintain the proper pH for flavor and setting characteristics. Historically, a small amount of salt was added as a flavor enhancer

Gelatin desserts can be prepared using either Type A or Type B gelatin with Blooms between 175 and 275. The higher the Bloom the less gelatin required for a proper set (i.e. 275 Bloom gelatin will require about 1.3% gelatin while a 175 Bloom gelatin will require 2.0% to obtain an equal set). Sweeteners other than sucrose can be used.

Gelatin in Meats – Gelatin is used to gel aspics, head cheese, soups, chicken rolls, glazed and canned hams, and jellied meat products of all kinds. The gelatin functions to absorb meat juices and to give form and structure to products that would otherwise fall apart. Normal usage level ranges from 1 to 5% depending upon the type of meat, amount of broth, gelatin Bloom, and texture desired in the final product.



Clarification of Beverages and Juices – Gelatin has traditionally been used to clarify wine, beer and fruit juices. Fining of these beverages requires only 40 to 80 parts per million of a 100 to 200 Bloom gelatin. In practice a dilute (1-3%) gelatin solution is introduced into the top of the tank and then allowed to settle before filtration.

Special Dietary Uses – Gelatin in hydrolyzed form is used to protein fortify dietary foods. Dried, hydrolyzed gelatin contains over 92% protein. Typically it is blended with other hydrolyzed proteins to balance the nutritional aspects of the amino acids. Soups, shakes and fruit drinks are common uses for gelatin hydrolysates.

Dietary concerns with collagen protein have been misunderstood for many years. While collagen has been described as an empty protein, or one having little nutritional value, it does in fact contain many essential amino acids, and is readily digestible.

C. E. Bodwell (53) reported that collagen can replace 30-40% of the protein in meat and still deliver a protein efficiency ratio greater than 2.0. He went on to state that in practice, the addition of collagen to meat products at levels of 25-30% would not be expected to have a significant effect on the protein nutritional status of individuals consuming meat products. In the U.S., an excess of protein is routinely consumed and marginal levels of tryptophan are probably not of serious concern, stated Dr. Bodwell.

The digestibility of collagen is very high. Laser-Reutersward et al. (54) demonstrated that in rats, over 90% of collagen was truly digestible, regardless of whether the collagen was heat treated or not.

Rogowski (55) graphically showed that mixtures of beef muscle and gelatin actually increased the biological value by 7% when gelatin was added as 16% of the mixture. A 50/50 blend of gelatin/beef muscle had the same biological value as beef muscle alone. The point is that although humans should consume combinations of proteins from various sources for optimum utilization of the amino acids, collagen (gelatin) can comprise from 25 to 50% of the protein and still meet or exceed adult nutritional needs (56).

Gelatin is not a complete protein for mammalian nutrition. It lacks the essential amino acid tryptophan and is deficient in sulfur-containing amino acids. Amino acid analysis of gelatins derived from common collagen sources is given in Table 1.

Gelatin is compatible with a wide variety of foods and ingredients. In fact, it has been used to help keep together ingredients that are incompatible. Some general nutritional information on gelatin is presented in Table 3.

TABLE 3. GELATIN NUTRITIONAL INFORMATION

	Type A	Type B
Moisture (%)	10.5 +/- 1.5	10.5 +/- 1.5
Fat (%)	0	0
Carbohydrates (%)	0	0
Ash (%)	.5 +/- .4	1.5 +/- .5
Sodium (ppm)	500 +/- 200	3600 +/- 1400
Phosphorous (ppm)	1 +/- 200	-
Iron (ppm)	4 +/- 2	15 +/- 10
Lead (ppm)	.002 +/- .002	.005 +/- .002
Zinc (ppm)	1.5 +/- .5	5 +/- 3
Nitrogen (%)	16.2 +/- .3	16.2 +/- .3
Calcium (ppm)	90 +/- 30	900 +/- 100
Potassium (ppm)	125 +/- 50	330 +/- 50
Calories / 100 grams	360	360

These figures are typical values or ranges which will vary greatly depending upon the type of raw material and methods of manufacture. They should not be used for label claims.

Gelatin is truly remarkable in terms of its many functional properties in food applications. A variety of examples are given in Table 4 (57).

TABLE 4. FUNCTIONAL PROPERTIES OF GELATIN IN FOODS

Function	Application
Gel former	Gelled desserts, lunch meats, confectionery, pate, consommé, aspics
Whipping agent	Marshmallows, nougats, mousses, soufflés, chiffons, whipped cream
Protective colloid	Confectionery, icings, ice creams, frozen desserts and confections
Binding agent	Meat rolls, canned meats, confectionery, cheeses, dairy products
Clarifying agent	Beer, wine, fruit juices, vinegar
Film former	Coating for fruits, meats, deli items
Thickener	Powdered drink mixes, bouillon, gravies, sauces, soups, puddings, jellies, syrups, dairy products
Process aid	Microencapsulation of colors, flavors, oils, vitamins
Emulsifier	Cream soups, sauces, flavorings, meat pastes, whipped cream, confectionery, dairy products
Stabilizer	Cream cheese, chocolate milk, yogurt, icings, cream fillings, frozen desserts
Adhesive agent	To affix nonpareils, coconut and other items to confections, to bond layered confections together, to bind frostings to baked goods, to bind seasonings to meat products.

PHARMACEUTICAL GELATINS

The use of gelatin in the manufacture of various pharmaceutical dosage forms dates back to the early 19th century and possibly earlier. Today, the commonly recognized dosage forms using gelatin are two-piece hard capsules, soft elastic gelatin capsules (Softgels), tableting, tablet coating, granulation, encapsulation and micro-encapsulation. All gelatins used meet or exceed the requirements of the current United States Pharmacopoeia and National Formulary



(1). The use of gelatin in the various dosage forms consumes approximately 17% of the total gelatin consumption worldwide. (58 – need new).

Two-Piece Hard Capsules – The Manufacture of hard gelatin capsules consists of the dipping of stainless steel mold pins into a gelatin solution, drying, stripping from the pins into a collate, trimming of the caps and bodies, and joining together for shipment. The strength and flexibility, the clarity of the gelatin, and the movability of the gelatin provide unique characteristics that allow the manufacture of various sizes, colors and designs for assuring a snap closure after filling (59).

A typical hard capsule gelatin specification would be:

Characteristic	Type A	Type B
Gel strength	240-300	200-250
Viscosity, mp	44-55	45-60
pH	4.5-5.5	5.3-6.5
Aerobic Plate Count		Max 1000 cfu/g
E. coli		Negative
Salmonella		Negative
Yeasts & Molds		Max 1000 cfu/g

Both types of gelatin are used, either in combination or separately, according to the final active fill product. Many hard capsules are produced today with a variety of tamper-evident closure systems that lock the cap to the capsule body and prevent easy opening. In addition, several sealing systems have been developed that place a colored gelatin band around the capsule, spot weld the capsule, gluing the capsule and heat sealing the filled capsule (60).

The typical hard capsule formula would be:

Gelatin	30%
Water	65%
Dye	5%
Pigment	As needed
Plasticizer	As needed



Soft Elastic Gelatin Capsules – Softgels, as they are commonly known today, utilize a gelatin solution that is plasticized with propylene glycol, sorbitol, glycerin or various approved mixtures. Soft gelatin capsules are one-piece and hermetically sealed to enclose a liquid or semi-liquid fill. Soft gelatin capsules are manufacture-formed, filled and sealed in one continuous operation (61).

The soft gelatin encapsulation process begins with the formation of two sheets called ribbons from a molten gelatin mass, each of which is passed over a die of the desired capsule size and shape. At the point where the two rotating dies meet, the capsule is formed and filled with a liquid that contains the active ingredient in a vehicle. The capsule is then washed to remove the lubricants and dried.

In 1932, R. P. Scherer developed the first rotary die encapsulation system: since that time the technology has been refined into a completely automatic process. The rotary die method has the advantage of producing a capsule with highly accurate dosage levels, can prevent photochemical deterioration of the active ingredient and masks unpleasant tastes.

A typical soft capsule gelatin specification would be:

Characteristic	Type A		Type B
Gel strength	150-200		125-175
Viscosity, mp	25-35		30-45
pH	4.5-5.5		5.3-6.5
Aerobic Plate Count		Max 1000 cfu/g	
E. coli		Negative	
Salmonella		Negative	
Yeasts & Molds		Max 1000 cfu/g	



Tablets – Tablets are defined as solid pharmaceutical dosage forms containing drug substances, with or without diluents, and prepared by compression or molding methods. Tablets are generally prepared by the compression method for most applications. The tablet formulation consists of an active or therapeutic ingredient and several inert materials known as excipients, which are classified as to the role in the tablet process.

All tablets contain diluents, binders, glidants and lubricants. Gelatin is used in the preparation of the active (granulation) and as a binder in the tablet.

The tableting process consists of several phases of preparation which are necessary to product the finished tablet.

The first step is typically the granulation of the active ingredient to a particle size close to that of the other ingredients. This is performed by various size enhancement techniques including granulation, extrusion and compression. In all three techniques gelatin is used for its adhesive properties. The natural tack of the gelatin assists in the agglomeration of the particles.

The second step is a granulation technique with all the excipients added. The granulation is controlled to produce a homogeneous and properly sized granulate. Gelatin solutions are used as the binder in this process to form larger agglomerates containing the active, binder, diluents and glidants (62). The use of gelatin in the granulation process provides an efficient means for reducing fines and maintaining physiological inertness.

Tablet granulates are then compressed into the proper shape, density and size by use of a tablet press. The compression exerted by the tablet press on the powder granulate is such that the agglomerates shatter and upon further compression lock together. The advantage of gelatin is that not only is the shattering of the agglomerates accomplished, but the adhesive properties of the gelatin act as an additional adhesive (63).

A typical tablet gelatin specification would be:

Characteristic	Type A		Type B
Gel strength	75-150		75-150
Viscosity, mp	17-35		20-35
pH	4.5-5.5		5.3-6.5
Aerobic Plate Count		Max 1000 cfu/g	
E. coli		Negative	
Salmonella		Negative	
Yeasts & Molds		Max 1000 cfu/g	

Tablet Coating – Tablets are generally coated to reduce dusting, mask unpleasant taste, and allow for printing and color coatings for product identification. The coating process is more and more becoming aqueous-based which allows for the use of gelatin. Typical formulations for coating include a sugar, pigment, and gelatin to act as a film former. The most popular coating method utilizes a roll coating pan and the addition of the coating solution as a fine spray (64).

Suppositories – Glycerinated gelatin is typically used as a vehicle for suppositories for insertion into the rectum, vagina or the urethra. The firmness of the finished product is adjusted by varying the gelatin concentration in the formula. The criteria for any suppository formulation are that the base (gelatin) be nontoxic and nonirritating to mucous membranes, compatible with a variety of drugs, the base melts or dissolves in body fluids, and the base should be stable on storage. Suppositories are generally molded by compression or by fusion molding. The gelatin base affords all the desired characteristics required by either method. The two types of gelatin each provide characteristics that are advantageous for formulation dependent upon the active and the area of application (64).

Type A gelatin is generally adjusted to an acidic pH which is below the isoelectric point, while a Type B gelatin is also adjusted to a pH that is acidic, but in this case the pH is above the isoelectric point. Thus the cationic, anionic, and the nonionic characteristics can be used to promote compatibility with the active, compatibility with the surrounding fluids and temperatures, and enhance or control the bioavailability.

The pH exists where the positive and negative charges are equivalent and the application of an electric charge has no effect. The principal chemical and physical characteristics of a gelatin solution are dependent upon the pH and the ionic strength of the media. The formulation and preparation of the gelatin can in fact modify the isoelectric point in such a way that various physical characteristics can be enhanced. The suppository dosage form is just one example of the use of varied isoelectric points that enhance the performance of the drug delivery system.

Gelatin Emulsions – Gelatin is recognized in many industries as a stabilizer, a texturizing agent, a film former and as a colloidal support media. The preparation of an oil emulsion with gelatin for use as a topical allows the oils to be stored and maintains droplet distribution and droplet size over extended periods. Depending upon the concentration and temperature, the emulsion can be free flowing, semi-solid or solid.

Microencapsulation – Gelatin is used to produce microencapsulated oils for various uses both in nutritional and pharmaceutical applications (65). The traditional method of encapsulation is known as coacervation in which the dispersed oil is encapsulated by gelatin at the interface between the aqueous phase and the nonaqueous phases. Common examples of this are vitamin supplements for various foods and for multi-vitamins. The size and formation of the spherical microcapsules can be controlled by various methods. Typical microcapsules range in size from 5 microns to 500 microns.

Absorbable Gelatin Sponge – Gelatin is used in the form of a sterile, water insoluble sponge (Gelfoam™) to control bleeding during surgery. It is later absorbed over a 4 to 6 week period (66).

Plasmas Substitues – Solution of modified gelatin (3.0 - 5.5%) and salts are commonly used as plasma substitute during emergency surgery.

Absorbable Gelatin Film – Another application is a sterile, non-antigenic, water-insoluble absorbable gelatin film (Gelfilm™) obtained from a specially prepared gelatin/formaldehyde solution (67).

Pastilles and Troches – These products are commonly used as cough drops. Like gelled confections, these products are unique in that in the mouth they are surrounded by a fluid that prevents the active ingredient from being concentrated and creating irritations.

Bacterial Growth Media – As with any pharmaceutical excipient, the level and type of bacteria found is always of concern. Pharmaceutical gelatin is highly purified and sterilized to eliminate these concerns. However, as gelatin is derived from collagen, the ability to perform as a nutrient is itself an application. Special grades of gelatin are useful in bacterial culture media. The specificity of the media to detect and count various bacterial strains is a useful diagnostic and research tool. A variety of media are available that utilize the nutrient properties of gelatin.

PHOTOGRAPHIC GELATINS



The use of gelatin in photographic emulsions dates back to about 1870 when Dr. Maddox of England replaced the collodion wet process with a gelatin emulsion which could be dried and was not required to be used immediately. Gelatin emulsions have, through the years, been continually improved in quality and speed. Gelatin is still the best medium known for making photographic emulsions (68-71).

Gelatin for photographic use is primarily Type B alkaline processed gelatin, especially for emulsion preparation. Type A gelatin has limited application for top coating and subbing. Although cattle hides have been used, Type B photographic gelatin is generally made from ossein derived from bone. Preparation and extraction of the raw materials are done under carefully controlled conditions to produce gelatin with desired photographic properties, such as varying degrees of sensitivity or inertness with minimal fogging properties.

Typical specifications for type B bone photographic gelatin are:

Moisture, %	10.5-12.5
pH*	5.65-5.85
Viscosity, mp *	78.0-95.0
Gel strength, grams	240-300
Absorbance, 420nm *	0.0-0.158
Absorbance, 650nm *	0.0-0.032
Viscosity loss, % **	< 5%

* Measured at 6.16% gelatin concentration and 40°C

** Measured at 10.0% gelatin concentration and 40°C: gelatin held for 24 hours at 37°C

Gelatin serves several functions in the preparation of the silver emulsions. It acts as a protective colloid during the precipitation of the silver halides; it is an important factor in controlling the size of the silver halide grains; and it protects the halide grains in the reducing action of the developer so that the reduction of these grains to metallic silver is in proportion to their exposure to light.

Formulas for photographic emulsions and procedures for their preparation can be found in the literature and patents. First, the emulsifying gelatin is dissolved in water and a solution of the required halide salts is added. Next a solution of silver nitrate is carefully added at a specified rate and with constant agitation. The mixture is then heated at a predetermined temperature up to 50°C for a set time. The salts are removed by decantation and washing after the gelatin containing silver halide is precipitated by coagulation. More gelatin and water are added to reconstitute to a proper consistency before chemical sensitization. Variations of the basic process to control silver halide crystal size distribution and size include processes to control nucleation and halide concentration during precipitation.

A final ripening and sensitization then takes place by heating to 50°C or above to reach the maximum or desired sensitivity. This procedure is used for the so-called boiled emulsion.

An ammonia emulsion is prepared similarly, but with the addition of ammonia in the early blending, and the use of lower ripening temperatures.

The emulsion is now ready to be coated on the desired batching film, paper or metal.

Gelatin itself contains natural ingredients which, though present in minute amounts, act as sensitizers in an emulsion. Other substances present naturally act as restrainers: they play an important role in emulsion preparation to offset reactions which cause fog.

TECHNICAL GELATINS

Technical gelatins differ from edible and pharmaceutical gelatins principally in that it is not essential that they meet the rigid specifications for human consumption set forth by the various municipal, state and federal governments to protect the health of the general public.

In many respects these gelatins are similar to edible gelatins. The test methods are generally the same as those used for edible gelatins. Both Type A and Type B gelatin may be used in the various applications that follow, but in certain applications one may be preferred over the other.

Coating and Sizing – Technical gelatins are used in the warp sizing of rayon and acetate yarns. The gelatin size adds strength to the warp and resistance to abrasion so that breakage of the warp is minimized. Gelatin is particularly well suited for this application because of its excellent solubility and film strength. It is applied in aqueous solution along with penetrating oils, plasticizers and antifoam agents before weaving, and later removed during finishing by washing with warm water.

Panama hats are sized with gelatin. Sizing helps preserve the shape of the hat while imparting resistance to water and dirt. An emerging technology involves the use of gelatin to size quartz fibers for space-age fabrics.

Paper Manufacture – Gelatin is used for surface sizing and for coating purposes. Either used alone or with other adhesive materials, the gelatin coating creates a smooth surface by filling up the small surface imperfections thereby ensuring improved printing reproduction. Examples include posters, playing cards, wallpaper, and glossy magazine pages.

High quality rag-based papers, such as those used for blueprints and currency, also feature a gelatin size coating. The result is a paper which has good moisture and abrasion resistance as well as good adhesion to printing inks (72). During manufacture the gelatin coatings are rendered insoluble by treatment with crosslinking agents.

The permanent crinkle in crepe paper is the result of gelatin sizing.

Printing Processes – For over a century, gelatin compositions have been used in printers' rollers and plate wiping rollers for multicolor presses and offset lithography.

Several photo-printing methods depend on the effect of light on a gelatin film which has been sensitized by treatment with potassium or ammonium dichromate. Examples of printing applications include carbon printing, collotype printing, silk screen printing, and photogravure.

Some high quality ink formulations include a small amount of gelatin as a suspension agent, a thickener or a protective colloid.

Protective Colloidal Applications – Much like edible gelatin is used for clarification of wine, beer and juices, technical gelatins are employed in the removal of extremely fine particles that cannot be settled out or filtered out of chemical solutions. Here gelatin is absorbed onto the surface of the particles effecting a coagulate that may be removed by settling or filtration. Approximately one pound of gelatin per ton of ore is used as a filtration aid during the extraction of uranium ore.

Gelatin is used to stabilize emulsions for water-proofing fabrics.

In suspension polymerization gelatin functions to control particle size as well as to prevent coalescence of the particles. About one pound of gelatin is sufficient to control particle size in a 10,000 pound batch of polyvinyl chloride.

Gelatin is added to electroplating baths to control the deposition rate. Similarly, gelatin functions as a zinc brightener by controlling the crystallization of zinc during deposit.

Matches – Gelatin is used almost universally as the binder for the complex mixture of chemicals used to form the head of a match (73). The surface activity properties of gelatin are important since the foam characteristics of the match head influence the performance of the match on ignition.

Coated Abrasives – Gelatin is used as the binder between the paper substrate and the abrasive particles of sandpaper. During manufacture the paper backing is first coated with a concentrated gelatin solution and then dusted with abrasive grit of the required particle size. Abrasive wheels, disks and belts are similarly prepared. Oven drying and a crosslinking treatment complete the process printing. (74).



Adhesives – Over the past few decades gelatin-based adhesives have slowly been replaced by a variety of synthetics. Recently, however, the natural biodegradability of gelatin adhesives is being realized. Today, gelatin is the adhesive of choice in telephone book binding and corrugated cardboard sealing.

The tackifying power of gelatin is used to advantage in the manufacture of packaging ribbons, decals, gummed tapes, glass laminates and composition cork gaskets. Hard cover book bindings typically utilize gelatin-based adhesives (75).

Gelatin Films and Light Filters – Films of various colors are produced with gelatin for use in photographic lighting and theatrical spotlights. Some bottle caps utilize gelatin films for shrunk-on seals.

Cosmetics – Although gelatin is used in cosmetic applications such as creams and wave-set lotions, the use of gelatin hydrolysates is more widespread in personal care products: especially in hair preparations.

Microencapsulation – Microencapsulation was first introduced commercially in the mid-1950's as the now well-known carbonless paper wherein a leuco dye material is enclosed in microcapsules coated onto a sheet of paper (46,47). When pressure from handwriting or typing breaks the microcapsules, the dye reacts with the coating on the next sheet to form a perfect image of the top sheet.

The applications for microencapsulation are literally limitless: dyes, drugs, flavors & fragrances and spray drying are just a few examples.

Other Applications: Analytcs is another area of interest where gelatin is used in ballistics testing in the Forensic Science laboratory. Gelatin is also used in Detergents and Cleansing Agents to minimize the accumulation of residues. Gelatin also has many uses in the Environmental Protection area.

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