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# Nonmeat Protein Applications in Meat Products

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# About Iowa

Iowa in U.S. Agriculture

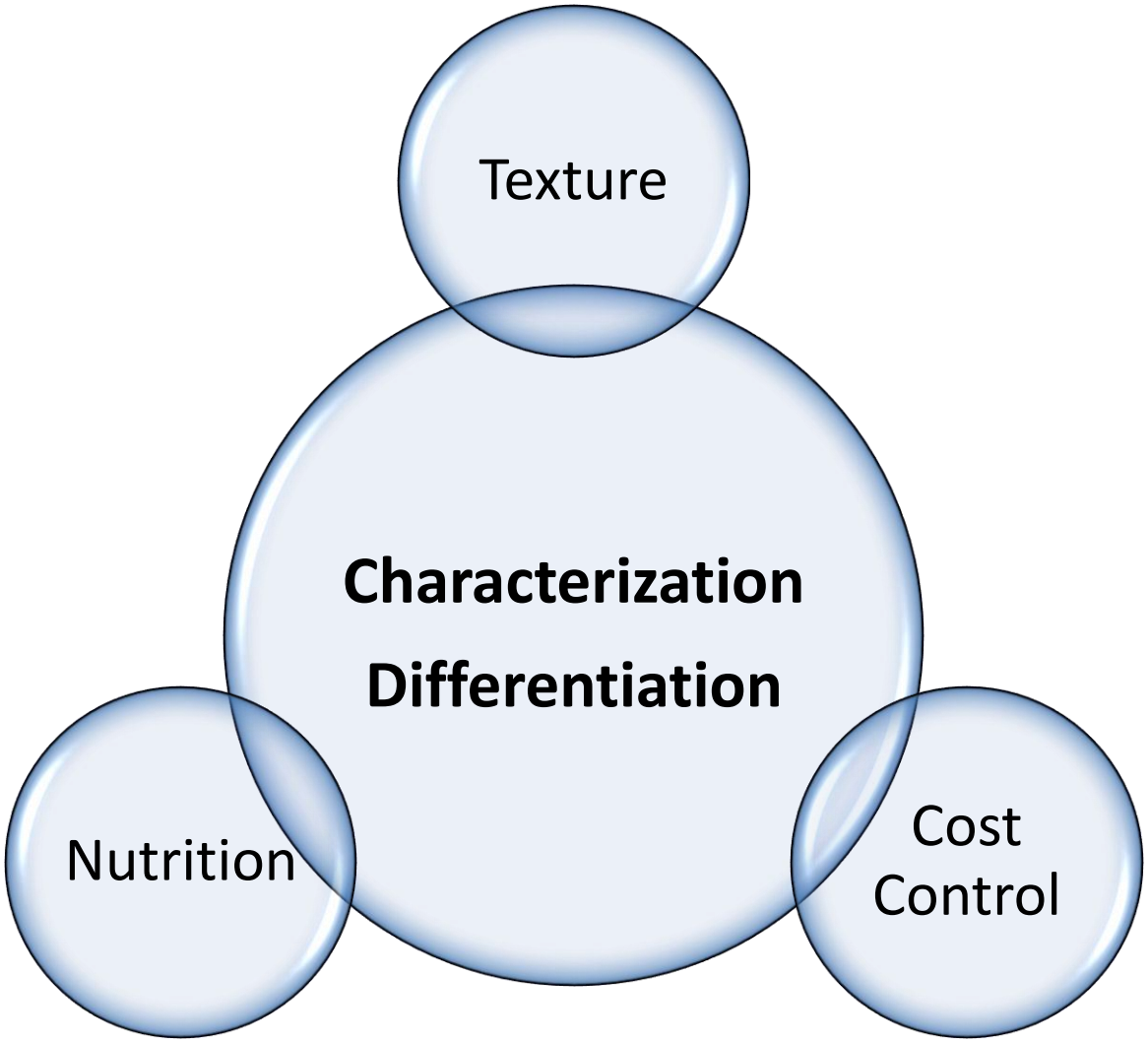
- #1 Pig and Hog Inventory and Value
- #1 Commercial Hog Slaughter
- #1 Live Animals and Meat Export Value
- #1 Soybean Production and Export Value
- #1 Corn for Grain Production
- #1 Feed Grains and Export Value
- #1 Egg Production
- #2 Red Meat Production
- #4 Cattle on Feed


http://www.ans.iastate.edu/section/meat/

# Nonmeat Proteins

- Definition
  - Protein-based ingredients external to formula meat
- Sources
  - Vegetable
  - Dairy
  - Meat by-products or meat

# Why use Nonmeat Protein Ingredients?



# General Functional Properties of Proteins

- Water-binding
  - Help retain meat water and added water to provide desired texture
- Gelation
  - Gelation properties are unique to each type of protein
- Fat Emulsification
  - Help stabilize fat in the meat batter
- Nutrition
  - Increase protein content of products
  - May help meet regulatory minimum protein content (where applicable) in a more economical way

# Vegetable Proteins

- Plant sources:
  - Soy
  - Wheat
  - Others:
    - Pea
    - Rice
    - Corn
    - Potato

# Soy Proteins

- Produced from defatted commercial soybean meal
- Approximate soybean composition
  - 40% Protein
  - 30% Carbohydrates
  - 20% Oil
  - 10% Moisture/ash
- Forms
  - Concentrates (≈70% protein on dry basis)
  - Isolates (≈90% protein on dry basis)
  - Which form to use depends on application
- Hydration
  - Should be hydrated prior to addition of other ingredients. Add after phosphate.
  - In some cases, may need to make a protein pre-gel.

# Applications

- General considerations
  - Hydration
    - Injection Applications
      - Should be hydrated prior to addition of other ingredients, but after phosphate.
    - Emulsified and coarse-ground systems
      - In some cases, it may help to make a protein pre-gel
      - However, new commercial high throughput processing lines have led many away from pre-gels and into direct addition
        - » Should add to lean meat early in the process to facilitate hydration

# Applications

- Soy Protein Concentrate (SPC)
  - Protein and insoluble carbohydrate fractions of soybean
  - Available in textured and powdered forms, or as
  - Textured SPC
    - Used to replace and/or simulate meat
      - e.g, vegetarian meat analogs; lower cost meat products

        (lower cost does <u>not</u> mean higher profit; must understand market segmentation)
    - Must hydrate prior to use to allow textured pieces to swell and assume "meat-like" texture

# Applications

Commercial vegetarian meat analogs that utilize textured SPC


# Applications

- Soy Protein Concentrate (SPC), cont.
  - Traditional SPC
    - Good water binding but low fat binding
    - Used in comminuted or coarse-ground meat products
  - Functional SPC
    - Good water <u>and</u> fat binding
    - Can be used in
      - comminuted or coarse-ground
      - Injected meat systems where injection level exceeds 30–35% of meat weight
    - Can be used in conjunction with other binders (e.g., carrageenan, starches) in high- or low-meat systems

# Applications

- Soy Protein Isolate (ISP)
  - Insoluble carbohydrates separated by centrifugation of soluble protein slurry
  - Physical properties can be modified by controlling pH prior to drying or manipulating process steps
  - ISP with <u>high</u> solubility, gelling, viscosity and emulsifying properties are used in comminuted or injected meat products
  - ISP with <u>moderate</u> solubility, gelling, viscosity and emulsifying properties are used in injected meat applications
  - Can be used in conjuction with other binders (e.g., carrageenan, starches) in high- or low-meat systems

# Wheat Proteins (Wheat Glutens)

- Made by washing wheat flour dough with water to remove carbohydrates, followed by drying
- Two protein fractions
  - Gliadins
    - Alcohol-soluble
    - Provide viscosity and extensibility
  - Glutenins
    - Alcohol-insoluble
    - Responsible for strength, elasticity and cohesion
- Application in meat is mostly limited to use of textured form to simulate meat, as in meat analog product
- Concern over Celiac disease

# Dairy Proteins

- Two major groups
  - Caseins
  - Whey proteins

# Physicochemical Properties of Milk Proteins

| Protein | Total Milk Protein (%) | Molecular weight | Isoelectric pH | Main functionality |
|---|---|---|---|---|
| Caseins | 80.0 | | | |
| $\alpha_{s1}$-casein | 31.4 | 23,555 | 4.95 | Emulsification |
| $\alpha_{s2}$-casein | 8.2 | 25,238 | 5.29 | Emulsification |
| β-casein | 29.1 | 24,028 | 5.32 | Emulsification |
| κ-casein | 10.3 | 19,038 | 5.53 | Emulsification |
| Whey proteins | 20.0 | | | |
| β-lactoglobulin | 10.0 | 18,362 | 5.2 | Gelation, foaming |
| α-lactalbumin | 3.8 | 14,174 | 4.7 | Emulsification |
| Serum albumin | 1.2 | 66,267 | 4.8 | Gelation |
| Immunoglobulins | 2.2 | 150,000–1,000,000 | 5.5-8.3 | Gelation |
| Proteose-peptone | 2.5 | 4,100–40,800 | | Water binding |

Data compiled from Walstra and Jenness (1984), and Modler (2000).

Source: Xiong, Y. L. (2009). Dairy proteins. In R. Tarté (Ed.), *Ingredients in meat products: Properties, functionality, and applications* (pp. 131–144). New York: Springer Science + Business Media.

# Nonfat Milk Solid (NFMS)

- Also known as Skim Milk Powder (SMP), Nonfat Dry Milk (NFDM)
- Composition
  - Protein 34.0–37.0%
  - Fat 0.6–1.25%
  - Lactose 49.5–52.0%
  - Ash 8.2–8.6%
  - Moisture 3.0–4.5%
- Functional properties
  - Good water binding and fat emulsification properties
  - Disadvantage: high lactose content can cause formation of Maillard reaction products
- Application
  - Commonly used as a filler in various meat products, such as frankfurters, bologna and meatballs

# Caseins

- Biochemical properties
  - $\alpha_{s1}$-, $\alpha_{s2}$, β-caseins precipitate in presence of calcium
  - K-casein is calcium insensitive
  - Are amphiphilic and, therefore, work well as emulsifiers
  - Also susceptible to transglutaminases
- Functional properties
  - Excellent solubility, water holding and emulsification properties
  - Sometimes partially hydrolyzed to improve water binding
- Application
  - Comminuted and coarse-ground products

# Whey Proteins

- Proteins that remain soluble after casein precipitation during cheese making
  - β-Lactoglobulin, serum albumin, immunoglobulins, proteose-peptone
- Commercially available as concentrates (WPC) or isolates (WPI)
- Functional properties
  - Standard whey proteins shown to ↑ water holding but ↓ gel strength in comminuted products
  - Partially denatured (pre-heated) WPI or WPC possesses enhanced gelling and water holding properties
- Application
  - Comminuted products, "enhanced" meats

# Milk Protein Concentrate and Isolate

- Obtained by treatment of NFDM to remove most of the lactose and soluble minerals
- Range in protein content from 42% to 85%
  - MPC 42, MPC 70, MPC 80, MPC 85, MPI (>90% protein)
- Suitable for applications were lactose is not desired

# Applications of Dairy Proteins in Meat Products

| Protein ingredient | Principal functional property | Application | Example |
|---|---|---|---|
| Nonfat milk solid (skim milk powder) | Texturization, flavor, emulsification | All meat products | Breakfast sausage, frankfurters, meat-based gravies |
| Sodium caseinate | Emulsification, texturization, meat-binding | Sausage, emulsion-type meats | Uncured pork sausage, frankfurters, turkey rolls |
| Partially hydrolyzed caseinate | Emulsification, texturization, water-binding | Sausage, emulsion-type meats, gravies | Fish balls, pork balls, beef patties, chicken nuggets |
| WPC or WPI | Water-binding, gelation, inhibiting pink color | Injected meats | Fresh sausage, turkey patties, boneless ham |
| Preheated WPC or WPI | Gelation, texturization | Sausage, emulsion-type meats | Fresh or cured sausage, boneless ham |
| Texturized WPC or WPI | Texturization, emulsification | Sausage, emulsion-type meats | Beef sausage, frankfurters |
| Partially hydrolyzed WPI | Antioxidant | All meat products | Precooked beef and pork patties |

Source: Xiong, Y. L. (2009). Dairy proteins. In R. Tarté (Ed.), *Ingredients in meat products: Properties, functionality, and applications* (pp. 131–144). New York: Springer Science + Business Media.

# Meat Protein Ingredients

- Group of high-protein ingredients derived primarily from meat animal by-products and sometimes from meat itself

## Main types of non-meat ingredients derived from edible animal by-products

| Source | Ingredients |
|---|---|
| Blood | Blood plasma (liquid, frozen, dried)<br>Whole blood (liquid and dried)<br>Red cell protein (decolorized)<br>Plasma transglutaminase |
| Bone | Gelatin (type B)<br>Edible bone collagen (ossein)<br>Bone collagen hydrolysates (stocks and broths)<br>Edible bone phosphate<br>Edible fat |
| Pig skin | Gelatin (type A)<br>Stocks and broths |
| Beef hides | Gelatin (type B) |
| Poultry skin (chicken, turkey) | Concentrated collagen<br>Stocks and broths<br>Edible fat |
| Collagen-rich tissues | Concentrated collagen<br>Collagen hydrolysates |

Source: Tarté, R. (2009). Met-derived protein ingredients. In R. Tarté (Ed.), *Ingredients in meat products: Properties, functionality, and applications* (pp. 145–171). New York: Springer Science + Business Media.

# Collagen

- Family of insoluble fibrous proteins found in all multicellular organisms, is one of the most abundant proteins in nature
- Most abundant protein in mammals
  - 25–30% of total body protein
  - 1–2% of bovine skeletal muscle
  - 4–6% of high-connective tissue muscles
- Major component of skin, bone, cartilage, tendon, blood vessels, basement membrane (endomysium), and teeth
- Rod-shaped molecule approx. 300 nm in length and 1.5 nm in diameter.
- Basic subunit, tropocollagen (mol wt 300 kDa), consists of three helical polypeptide α-chains (α1, α2, and α3) coiled around one another into a triple-stranded superhelix stabilized by hydrogen bonds

# Collagen

- Unique amino acid (AA) composition and sequence.
  - 33% glycine
  - 12% proline
  - 11% hydroxyproline
  - 11% alanine
  - No tryptophan
  - Contains unusual AAs 3-hydroxyproline, 4-hydroxyproline, and 5-hydroxylysine
  - Chain has three amino acid residues per helical turn, with every third AA being glycine.

# Collagen

- Properties
  - Sources for use in processed meats include skin, hide, bone, offal, and skeletal muscle
  - Addition to meat products
    - As a constituent of high-collagen meat raw materials
      - Typically high-collagen tissues, such as skeletal muscle connective tissue, beef hides, pork skins, and tripe
    - In concentrated form as a direct additive.
      - Has been concentrated from bone (as bone collagen extract), beef hides, pork skins, and skeletal meat connective tissue
      - Physical extraction and/or concentration of collagen usually involves particle size reduction of collagen—or high-collagen materials—by cutting, grinding, flaking, milling, or a combination of these

# Collagen

- Applications
  - Raw (high-collagen raw materials)
    - Collagen triple helix begins to unravel, shrink and dissolve at 60–65°C, which may cause disruption of the myosin gel in comminuted meat products
    - To avoid this, limit high collagen trimmings to 2–3% (especially from older animals), avoid excessive chopping, increase pH and ionic strength, cook in stepwise manner

# Collagen

- Applications
  - As added ingredient
    - Research has focused on its extraction from various sources (species, anatomical locations) and by various means, and on its application in various types of meat products
    - Various commercial forms of functional concentrated collagen ingredients can be made by low-temperature rendering systems
    - Have been used I whole muscle and comminuted products
    - Have been shown to increase cook yield, reduce expressible moisture and help reduce package purge
    - Commercial forms may differ from each other, so TEST!

# Gelatin

- Gelatin is the heat-denatured, partially hydrolyzed form of native, insoluble collagen. I
- Amorphous mixture made up primarily of three types of free chains:
  - α monomers (mol wt 100 kDa)
  - β dimers (mol wt 200 kDa)
  - γ trimers (mol wt 300 kDa) (Kijowski, 2001).
- Denaturation temperature of collagen varies by species and hydroxyproline content

# Gelatin

- Commercial gelatin is obtained primarily from raw materials rich in type I collagen
  - Pork skin and bones, beef hides and bones, calf skin
  - Through very controlled stepwise process collagen is hydrolyzed followed by heating to denature the molecule to gelatin
- Types of gelatins
  - Type A (isolectric point = pH 6–9)
    - Obtained by mild acid pretreatment of physiologically young collagen (e.g., pig skins), which have high proportions of acid and heat labile cross-links
  - Type B (isoelectric point = pH 4.8–5.2)
    - Obtained by severe alkali pretreatment of the more highly cross-linked collagen from bone and cattle hides

# Gelatin

- Commercial gelatin extracts are mixtures that contain not only α, β, and γ chains, but also other larger (up to mol wt $10^6$) and intermediate size molecules as well
- Properties are dependent on spectrum of molecular species and are affected by:
  - Changes in the manufacturing process
  - Nature of starting raw materials
- Type A gelatins are higher in lower molecular weight chains than type B
  - Decrease in mol. wt. → gel strength and viscosity

# Gelatin

- Gelatin hydrolysates
  - Obtained by controlled enzymatic hydrolysis of gelatin solutions to reduce the protein's molecular weight to a desired range
  - Properties similar to gelatin except that, due to their lower molecular weight, they are more easily dispersible in cold water and do not gel at regular processing temperature

# Gelatin

- Properties
  - Incomplete protein: deficient in methione and devoid of tryptophan
  - Excellent functional properties
    - Gelling, melting (melts at <35ºC), stabilization, film-forming, texturizing, and water-holding
  - Gels are thermoreversible
- Applications
  - Aspics, canned hams and canned sausages.
  - Have been proposed as external coatings to protect meat against color loss, aroma deterioration and purge losses
  - GRAS status in U.S., so no maximum allowable level

# Stocks and Broths

- High-protein (up to 94%) products
- Derived from:
  - Liquid stream of low-temperature rendering of soft materials such as meat lean and fatty trimmings, pig skins, and poultry skins, or
  - High-temperature rendering of soft materials or hard materials such as edible bones
- Collagenous in nature

# Stocks and Broths

- Applications
  - Bases for meat and reaction flavor manufacturing
  - Protein sources and flavor enhancers for processed meat products
  - Use in sausage products to increase the protein content
  - Can act as stabilizers, emulsifiers, and binders, although that is not usually their primary purpose when added to processed meat products
  - In U.S. ingredients such as dried stocks, dried broths, and meat extracts must be designated as “dried (species) stock,” “dried (species) broth,” and “(species) extract” (e.g., “dried chicken stock,” “dried beef broth,” “pork extract,” etc.)

# Hydrolysates and Flavors

- Obtained from meat by-products such as bone residues, mechanically separated meat (MSM), bone cakes from mechanical separation, trimmings, blood plasma and red blood cells among others, meat (e.g., myosin and collagen)
- Chemical or enzymatic hydrolysis
- Properties such as emulsion stability, viscosity, and gel-forming ability decrease as degree of hydrolysis increases
- As DH increases, the flavor contribution of protein hydrolysates increases, primarily due to the presence of low-molecular weight flavor components (e.g., amines, amino acids, and small peptides) and flavor precursors (e.g., nucleotides and organic acids)

# Hydrolysates and Flavors

- Choice of meat protein hydrolysate dictated by specific functional properties desired for each particular application and may also be limited by commercial availability
- In U.S. "hydrolyzed protein of slaughtered animal species and tissue of origin, other than gelatin, must be indicated, e.g., 'hydrolyzed beef plasma,' 'hydrolyzed pork stock,' and 'hydrolyzed pork skin'"

# Blood-Derived Proteins

- Blood fractions
  - 60–80% Plasma
  - 20–40% Cells (mostly red cells, with smaller amounts of white cells and platelets)
- Deficient in essential amino acids methionine and isoleucine

# Blood-Derived Proteins

## Composition of blood and of its major fractions

| Blood fraction | Protein (%) | Moisture (%) |
|---|---|---|
| Whole blood | 17–18 | 75–82 |
| Plasma | 6–8 | 90–92 |
| Cells | 34–38 | 60–62 |
| Dried plasma | 70–95 | 5–10 |

Source: Tarté, R. (2009). Met-derived protein ingredients. In R. Tarté (Ed.), *Ingredients in meat products: Properties, functionality, and applications* (pp. 145–171). New York: Springer Science + Business Media.

# Blood-Derived Proteins

- Blood Plasma protein (BPP)
  - Functional properties attributed to its albumin, globulin, and fibrinogen content
  - Good gelation, emulsification and solubility
  - Gelation
    - Strong, irreversible gel at protein concentrations of 4–5% when heated to at least 70°C
    - Increasing temperature to 90–92°C will result in an even firmer gel
    - Suitable for products subjected to high temperatures (e.g., canned)
    - Gelation temperature, hardness, elasticity and water holding increase with increasing pH
  - Emulsification
    - Improve emulsion stability, texture, juiciness and peelability
    - Useful in comminuted products

# Blood-Derived Proteins

- Blood Plasma protein (BPP), cont.
  - Solubility
    - Very soluble over pH 5.0–8.0
    - Ideal binder for meat products where solubility is critical, e.g., injected products

# Blood-Derived Proteins

## Major plasma proteins and their basic properties[1]

| Protein | Plasma protein (%) | pI | Molecular weight (kDa) |
|---|---|---|---|
| Serum albumin | 56 | 4.8–4.9 | 69 |
| $\alpha_1$-Globulins | 5.3 | 2.7–4.4 | 44–435 |
| $\alpha_2$-Globulins | 8.4 | 3.6–5.6 | 41–20,000 |
| β-Globulins | 11.5 | 3.6–5.9 | 80–3,200 |
| γ-Globulins | 15 | 5.8–7.3 | 100–160 |
| Fibrinogen | 0.6 | – | 340 |

Adapted from: Gorbatov (1988); Howell (1992).
[1] Protein levels vary with animal species and age.

Source: Tarté, R. (2009). Met-derived protein ingredients. In R. Tarté (Ed.), *Ingredients in meat products: Properties, functionality, and applications* (pp. 145–171). New York: Springer Science + Business Media.

# Blood-Derived Proteins

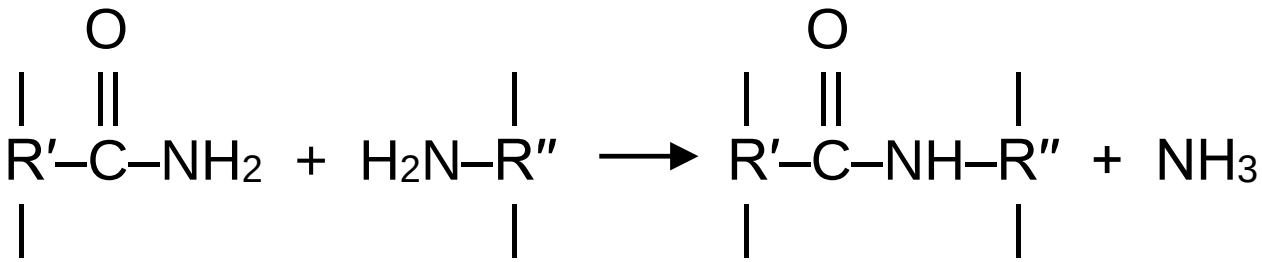
- Plasma Protein Fractions
  - Plasma can be further fractionated into its major constituents—albumin, globulins, and fibrinogen
  - Precipitation and removal of fibrinogen leaves behind serum, which can then be further fractionated into albumin and globulins
  - High degree of synergy between them
- In U.S. blood plasma is permitted in meat products

# Blood-Derived Proteins

- Plasma Transglutaminase (TGase)
  - Blood clotting Factor XIII ($Ca^{2+}$-dependent)
  - Can be used to modify texture and improve yields
  - Appropriate substrate should be added to improve reaction, maximize TGase effectiveness and reduce usage level
  - Can be used to bind uncooked meat pieces together
  - Can be used to improve the texture of processed meats, alone (via cross-linking of meat proteins) or in combination with other non-meat proteins added to the system, such as soy protein or casein
  - In U.S. permitted at up to 10%; words "Formed with Beef Fibrinogen and Thrombin" must appear either in the product name ame qualifier (at usage levels of less than 7%) (at usage levels of 7–10%) or in the product n

# Blood-Derived Proteins

Transglutaminase-catalyzed crosslinking reaction




Glutamine Lysine ε-(γ-glutamyl)lysyl isopeptide bond

# Blood-Derived Proteins

## Food protein substrate specificity of TGases of different origin[1]

| | Degree of cross-linking [2,3] | | | | | |
|---|---|---|---|---|---|---|
| | Pig erythrocyte TGase | | Bovine plasma TGase | | Bacterial TGase | |
| Substrate | – DTT | + DTT | – DTT | + DTT | – DTT | + DTT |
| α-Lactalbumin | – | ± | – | ± | + | ++ |
| β-Lactoglobulin | – | – | – | ± | – | ++ |
| Bovine serum albumin | – | + | – | + | – | ++ |
| Casein | – | ++ | ++ | ++ | ++ | ++ |
| Hemoglobin | – | – | ± | ± | ± | ± |
| Myosin | – | – | ++ | ++ | ++ | ++ |
| Glycinin | – | ++ | – | – | ++ | ++ |

From de Jong, Wijngaards, Boumans, Koppelman, & Hessing (2001).

[1] Experimental conditions: 37°C; pH 7.5.

[2] Symbols: (–) no cross-linking; (±) slow cross-linking; (+) moderate cross-linking; (++) fast cross-linking.

[3] DTT: Dithiothreitol; promotes unfolding of the protein chain by reducing disulfide bridges.

# Blood-Derived Proteins

- Hemoglobin and Red Blood Cells (RBCs)
  - 70% of total blood protein is hemoglobin
  - Limited use in meat products due primarily to the dark color and off-flavors they impart.
  - Can be used as color enhancers
  - In U.S., blood is permitted in products such as blood sausage, blood pudding, blood soup, and in beef patties, as long as a qualified product name is used (e.g., “Beef and Blood Patties” or “Beef Patties with Blood”). Must always be declared in ingredient statement.

Muito obrigado

Perguntas?

MEAT ISU LABORATORY
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