Gelation In Meat Batters

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Presenter

Introduction

When frankfurters, hot dogs or bologna are manufactured, the meats are extensively chopped (comminuted) to produce small particles. One can observe a heterogeneous mass of lean and fat transformed into a meat batter of homogeneous appearance. Meat batters are fluid and primarily composed of water, fat and protein. One key element in manufacturing these products is stabilizing the fat and moisture to prevent excessive losses or product failure. The meat proteins stabilize the fat; therefore, meat batters have historically been defined as meat emulsions. The colloidal chemistry definition of an emulsion – a two-phase dispersion of immiscible liquids – is a good representation of the raw meat batter.

Meat batters are considered an oil-in-water emulsion (o/w) and much of the pioneering work (see review by Saffle, 1968) focused on factors regulating emulsion stability. It was observed that emulsion stability varied with meat source and that meats could be classified according to their stabilizing ability. Each meat is assigned a bind constant, which is an experimentally derived value based in part on their emulsifying capacity (Carpenter and Saffle, 1964; Porteous, 1979), and these constants are used in formulating meat products.

Once the meats and ingredients are chopped and mixed into a homogeneous batter, thermal processing converts the system from a fluid to a solid. When processing is done under appropriate conditions, the fat remains dispersed in a two-phase continuous system of water and a protein matrix. The cooked product can be characterized by textural and water-holding properties; attributes more appropriately associated with gels than emulsions. Is a meat batter a gel or an emulsion? One could argue that the raw batter is an emulsion (key points being fluid and a oil-in-water dispersion) and the cooked frankfurter is a gel (because it is a solid with a continuous protein matrix). That debate is one which will continue for some time. The objective of this review is to consider textural and water-holding properties of cooked comminuted meats under the framework of gelatin theory.

Gels and Gelation

Types of Gels

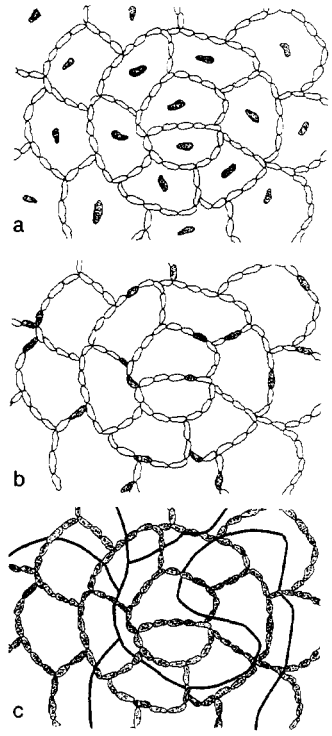
The simplest type of protein gel is one which is formed from a single polypeptide. Heating causes the molecule to unfold and a matrix is created through intermolecular interactions (i.e. gelation of bovine serum albumin). By comparison, meat batters are a much more complex system which contains many types of proteins, lipids and ingredients (salts, nitrites, sugars, etc.). Frankfurters and other finely-comminuted meat products can be classified as multicomponent gels. Tolstoguzov and Braudo (1983) defined three types of multicomponent gels, filled mixed and complex.

In filled gels (Fig. 1a), one macromolecule is forming the gel matrix while the other molecules are acting as fillers within the interstitial spaces. The filler molecules can affect certain textural properties and/or water binding. A filled gel would form when starch or a non-gelling protein is added to meat batters (Foegeding and Lanier, 1987).

A complex gel has a matrix produced by interactions among more than one component (Fig. 1b). For example, fibrinogen interacts with myosin during gelation and this would result in a complex gel when blood plasma is added to comminuted meats (Foegeding et al., 1987).

Mixed gels (Fig. 1c) are those in which the gelling

Figure 1



Schematic representation of gels: filled (a), complex (b), and mixed (c).

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macromolecules independently form two or more three-dimensional networks without interactions among the polymers. The formation of mixed gels in meat batters would require independent gelation within different fractions of muscle proteins, or addition of a nonmeat gelling agent. From the limited data available, it was suggested that mixed and complex gels have the potential to produce textural characteristics which cannot be achieved with either component individually (Tolstoguzov and Braudo, 1983).

Rheological Analysis

The formation of filled, mixed and complex gels can be investigated by analysis of physical/chemical properties (intermacromolecular interactions), microstructure (visible and electron microscopy) and gel rheology. This review will concentrate on rheological analysis, which is not meant to slight the other methods. Indeed, one type of analysis alone is not sufficient to establish the type of multicomponent gel.

Rheological properties of gels can be determined at low strains (deformations), where care is taken to prevent sample destruction. These conditions permit a dynamic measure of viscoelastic behavior which can be monitored with respect to time and temperature (Hamann, 1987). Rheological analysis can determine rigidity or shear modulus (stress/strain), storage modulus (describes the elastic nature of the material), and loss modulus (describes the viscous nature of the material), which are physical properties of the material that are not dependent on sample size or shape. These are fundamental properties of materials and can be determined by a variety of methods. Brownsey et al. (1987) showed that a filter particle will increase the shear modulus of a gelatin gel matrix in accordance with the rigidity of the particle. If the filler particle shear modulus is equal to that of the gel matrix, the shear modulus of the filled gel will not change. However, if the shear modulus of the filler particles is greater than that of the gel matrix, the shear modulus of the filled gel will increase in relationship to the volume fraction of the filler. Furthermore, particle size does not seem to have a great effect on shear modulus. Filler beads of equal shear modulus but ranging in diameter from 20-50 μm to 100-300 μm were not significantly different (Brownsey et al., 1987).

While the evaluation of rheological properties at nondestructive strains is beneficial in understanding gelation, the results are not always pertinent to textural properties perceived by sensory analysis (Hamann, 1987). This is because sensory texture is determined by deforming the sample to failure.

Rheological properties determined at failure have been shown to correlate with sensory perception of texture (Montejano et al., 1985). Shear stress at failure (shear force/area of shear surface) and shear strain at failure (shear deformation/thickness of layer sheared) are physical properties of gels which can be determined by mathematical analysis of samples of various simple shapes in compression, torsion or tension (Hamann, 1983). Conversely, Instron texture profile analysis parameters (force to fracture, hardness) and other properties, such as gel strength, are empirical and dependent on sample size and shape. Furthermore, determination of shear stress and strain gives a more complete description of texture than single property evaluations. For example, a soft, deformable frankfurter may have the same failure stress (hardness) as a rigid, brittle frankfurter; however, the failure strain (deformation) would vary greatly between the samples.

Rheological Analysis of Multicomponent Gels

Rheological analysis of failure stress and strain can be used to distinguish between filled gels and mixed/complex gels. Properties of the gel matrix, which would be indicative of mixed or complex gels, appear to be reflected in failure strain and stress. By contrast, fillers tend to increase the failure stress and not the strain. This was shown to be true for carbohydrate filler particles in a gelatin gel matrix (Brownsey et al., 1987).

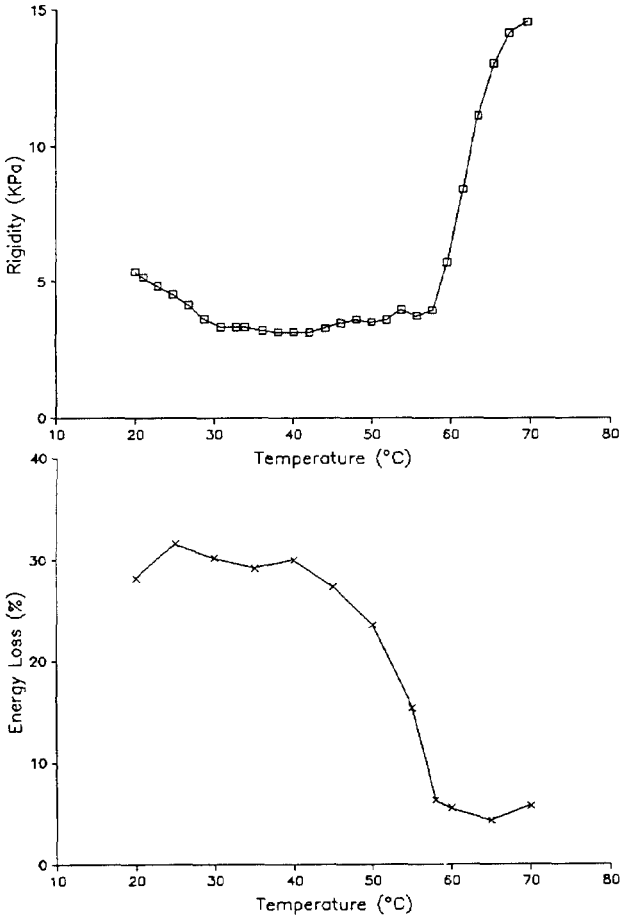
Gelation in Comminuted Meats

Gel Formation During Cooking

Heating meat batters causes structural changes in the muscle proteins which favor intermolecular protein interactions. Protein aggregation progresses to gelation under favorable conditions. The transformation from a raw batter to a gel can be determined by changes in the viscoelastic properties. The shape of the force-deformation curve from small, nondestructive strains can be used to determine the amount of energy lost during deformation (Montejano et al., 1983). In a perfectly elastic system, all the energy of deformation is recovered after the force is removed, 0% energy loss. The energy of deformation in a viscous system would be lost as heat, 100% energy loss. Frankfurters have a major transition in energy loss at 45° to 55°C (Fig. 2) that indicates the change from a viscous (raw) batter to a gelled (elastic) cooked product (Saliba et al., 1987). The rigidity (shear modulus) of meat batters starts to increase at 58° to 60°C and continues to increase from 60° to 70°C (Fig. 2). The increase in rigidity can be viewed as development of the gel matrix structure. The reason for the time/temperature delay between energy loss and rigidity has not been determined. For example, it is not known if rigidity would incease at 50°C if a meat batter was held isothermally.

The effects of heat can be studied by heating for various time/temperature combinations and evaluating the cooled product. Textural and water-holding properties of meat batters processed under these conditions reflect changes due to heating and cooling. The gelation of meat batters between 40°C and 50°C can be observed by increases in the textural properties of hardness (force at the end of a compression), force to fracture (force required for initial failure) and shear stress at failure (Patana-Anake and Foegeding, 1985; Singh et al, 1985; Foegeding and Ramsey, 1987). In contrast, the water-holding ability does not change between 40°C and 50°C (Patana-Anake and Foegeding, 1985; Whiting, 1984). Between 50°C and 60°C, major changes take place. The textural properties of hardness, force to fracture and shear stress increase while the shear strain at failure (deformability) decreases (Patana-Anake and Foegeding, 1985; Singh et al., 1985; Foegeding and Ramsey, 1987). The water-holding properties also change. Moisture is released during heating (Patana-Anake and Foegeding, 1985; Whiting, 1984) or, in batters which do not have cooking losses,

Figure 2



Rigidity and energy loss transitions in a frankfurter butter during heating. Data from Saliba et al. (1987).

there is a decrease in the ability to hold moisture during centrifugation (Foegeding and Ramsey, 1987). These investigations suggest that textural and water-holding properties develop independently, although not exclusively.

Meat Batters as Filled, Mixed and Complex Gels

Components other than muscle proteins, such as nonmeat proteins, carbohydrates and lipid, can contribute to the texture and water-holding properties of meat batters. Their functional roles can be described under the definition of filled, mixed and complex gels. In all of the investigations covered in the following discussion there is a lack of information required to fully classify the type of gel; however, support for certain categories is discussed.

Lipid can function as a filler or, if protein-lipid interactions affect the gel matrix, the system would be a mixed gel. Increasing the fat content from 10% to 25.5% caused an increase in hardness and shear stress to failure, with no significant change in strain to failure (Foegeding and Ramsey, 1987). Fat was acting as a filler in that system. The filler effect of fat will vary in accordance with the texture of added fat. An increase in fat firmness causes an increase in force to fracture (Lee and Abdollahi, 1981).

Nonmeat proteins can combine with muscle proteins to form filled, complex or mixed gels. Parks and Carpenter (1987) investigated the effects of substituting meat with nonmeat proteins (nonmeat proteins referring to commercially available powders which also can contain fat, carbohydrate and minerals). The data presented did not allow for determination of gel type; however, it did show that soy flour and autolyzed yeast could decrease texture (rupture force) without a significant decrease in cook yields. Whey protein concentrate was shown to increase hardness without a significant change in cooked yield (Ensor et al., 1987). This once again demonstrates that water holding and texture are regulated by different factors.

Polysaccharides can be used as functional ingredients in muscle protein gels. Starch and kappa-carrageenan act as fillers, increasing shear stress to failure without changing shear strain at failure (Foegeding and Ramsey, 1987; Wu et al., 1985). The result is quite different with pregelatinized starch. The stress and strain at failure are decreased and the heated mixture is more paste-like than gelled (Wu et al., 1985). Xanthan gum, a non-gelling, viscous polysaccharide, has the same effect as pregelatinized starch (Foegeding and Ramsey, 1987). The data suggest that muscle protein gelation will be disrupted if there is competition for the available water. When iota-carrageenan is added to meat batters at 1% (w/w/), the water-holding ability, shear stress and shear strain at failure are increased (Foegeding and Ramsey, 1987). This suggests that the gel matrix is altered and a mixed or complex gel is formed.

Future Research

The classification of frankfurters, hot dogs and bologna as multicomponent gels provides a framework to study the mechanism of ingredient and processing effects. For example, there are applications where an increase in water holding is necessary but the texture should not be altered. By combining processing factors and ingredients, it is feasible that this could be accomplished. A long-range goal would be to generate a data base that could be used to produce comminuted products of specified textures (from soft to chewy), water-holding and fat-holding properties. This type of technology would be of benefit in producing non-traditional products, such as low-fat frankfurters, with the texture of traditional products.

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