RECIPROCATION SESSION

Functionality of Proteins in Meat Products

Youling L. Xiong* and P. Brett Kenney

Introduction

Quality attributes of meat and meat products are often described in terms of protein functionality, i.e., any inherent or process-generated property of proteins that affects physical and sensory characteristics of raw and finished products. For example, in comminuted meats, the ability of a muscle mince to form a three-dimensional gel matrix, to emulsify fat, and to retain natural and added water are some of the most important functional properties. These physicochemical processes greatly influence product texture, integrity, physical stability, cooking yield, appearance, and hence, palatability and consumer acceptance.

Processed meats are heterogeneous systems composed of muscle itself and various nonmuscle ingredients including polysaccharides, flavor agents, salt, and phosphates. It is well established that proteins are largely responsible for the functional characteristics of muscle foods. This conclusion is based on the pioneering research conducted by Fukazawa and coworkers in the early 60's (Fukazawa et al., 1961) and on numerous studies that subsequently followed (for review, see Acton, et al., 1983; Asghar et al., 1985, Gordon Barbut, 1992; Xiong, 1997). Today, two questions are still frequently asked by meat processors: 1) what are the major factors affecting meat protein functionality, and 2) how can we predict product quality from functional properties of raw material constituents? Data generated from model systems are sometimes difficult to extrapolate to *in situ* conditions of processed meats, because the environment of model systems is usually oversimplified from that of processed meats in order to address specific questions. Nevertheless, it is generally agreed that functional behaviors of proteins in processed meats and in isolated systems are controlled by the same factors, e.g., characteristics of the protein itself, temperature, pH, and ionic conditions. For example, emulsification and gelation properties of isolated myofibrillar proteins can explain most, if not all, of the stability issues relevant to raw and cooked meat batters (Galluzzo Regenstein, 1978; Jones, 1984; Barbut, 1995). The hydration properties of salted meat clearly reflect protein-water interaction and salt-induced structural changes in the myofibrillar matrix (Offer Trinick, 1983; Parsons Knight, 1990). Similarly, bind strength and thus, texture and integrity of restructured meat products can be largely accounted for by the gel-forming properties of salt-soluble proteins extracted to the meat particle surface or added to the product formulation (Fukazawa et al., 1961; Siegel Schmidt, 1979; Kenney et al., 1992; Xiong et al., 1993).

Despite extensive research conducted in the field of muscle protein functionality, meat scientists are constantly challenged by new questions and pressing issues. For example, we have changed the traditional way of making sausage with up to 30% fat to new practices of making sausage with less fat (low or no fat) but up to almost 40% added water. This change translates into a lower ionic strength for the aqueous solution (in which proteins are bathed) from about 0.82 to 0.50, assuming muscle contains 75% water, and 2.5% salt is added to both types of products. The minimal ionic strength for solubilizing and extracting myofibrillar proteins is near 0.6. Therefore, how would protein behavior be affected by the reduced ionic strength, and what should meat processors be concerned about in making low-fat products with a much diluted salt concentration?

In this reciprocation session, we will try to address some of the questions and concerns, and hopefully this will stimulate follow-up discussion about the topic of muscle and protein functionality. In particular, we will focus our discussion on the influence of various factors, inherent to muscle and processing, on the functionality of proteins. Methods that may be used to measure protein functionality will also be discussed.

Factors Affecting Meat Protein Functionality

The single most important "functional" protein in meat is myosin or its complex with actin, actomyosin. Because it has a well-balanced hydrophilicity-hydrophobicity and a large, long fibrous structure, myosin is capable of forming highly elastic gel matrices and a cohesive, rigid fat globule membrane in comminuted and emulsified meats. The relatively high content of sulfhydryl groups from cysteine also makes myosin susceptible to oxidation, which at times could be desirable in terms of forming cross-linked network systems via the disulfide bonds (Srinivasan Xiong, 1997). The concentration of proteins, including myosin and actomyosin, in the aqueous protein extract or exudate drawn to the meat par-

---

Youling L. Xiong, Department of Animal Sciences,
206 Garrigus Building, University of Kentucky, Lexington, KY
40546-0215; P. Brett Kenney, Division of Animal and
Veterinary Sciences, West Virginia University,
Morgantown, WV 26506-6108. E-mail address: ylxiong@pop.uky.edu

Reciprocal Meat Conference Proceedings, Volume 52, 1999.

ticle surface during processing is determined by many factors. It generally increases with time of extraction (tumbling, massaging, chopping, etc.), with increases in salt concentration (ionic strength), and with an increase in pH, to name a few. Of course, there is hot-boning (prerigor) vs. cold-boning (postrigor). Exudate extracted from prerigor muscle (less contracted) contains a large quantity of free myosin as opposed to actomyosin extracted from postrigor muscle (more contracted). Processing conditions that favor solubilization and extraction of myosin usually lead to enhanced functionality of the protein exudate.

Functional properties of meat proteins are influenced by the presence of nonmuscle ingredients whether they are ionic or nonionic in nature. Phosphate compounds, particularly pyro- and tripolyphosphates, have remarkable effects on hydration of low-salt (< 1.5% NaCl) meat due to their ability to increase electrostatic repulsion between myofilaments and possibly to dissociate the actomyosin complex (Bendall, 1954; Granicher Portzehl, 1964; Offer Trinick, 1983). However, phosphates have been found to interfere with protein gel network formation in comminuted meats (Robe Xiong, 1993; Torley Young, 1995). Likewise, many polysaccharides (gums), although exhibiting remarkable water-binding potential themselves, tend to diminish the gelling and emulsifying ability of meat proteins, thereby weakening the texture of restructured meats, by competing for water and disrupting protein-protein and protein-lipid interactions (Xiong Blanchard, 1993; Xiong et al., 1999). On the other hand, some cations, Zn, Mg, and Ca in particular, when used at low concentrations under certain specific processing conditions, are able to enhance gelation, emulsification, and water-binding by proteins in processed meats (Barbut Mittal, 1988; Xiong Brekke, 1991; Nayak et al., 1998).

Measurement of Meat Protein Functionality

A variety of instruments have been developed over the years to assess functional properties of food proteins. Water-holding capacity of meat or protein products can be measured by centrifuging the sample at a certain speed and time then determining the amount of water (juice) expressed, or by pressing the sample against a filter paper without the application of centrifugal force. Other techniques used to measure water-binding in meat and meat products include NMR (Lillford et al., 1980) and NIR (Forrest, 1998). Recently, optical sensors have been developed to determine emulsifying capacity of proteins in comminuted batters (Barbut, 1999). As to gelation studies, static, and dynamic rheological tests are employed. For static compression and torsion tests, a meat or protein gel sample is compressed or twisted and the stress and strain values are recorded. For dynamic measurement, the real-time development of an elastic protein network system and the sol-to-gel transition can be readily detected, allowing for the elucidation of the mechanism of protein gelation (Xiong Blanchard, 1993). Emulsifying activity of muscle proteins as well as stability of protein-stabilized emulsions can be assessed by monitoring physical changes in the emulsion (fat particle size, coalescence, etc.) during homogenization or during storage. Both scanning and transmission electron microscopic examinations are widely performed to reveal the ultrastructure of meat protein-fat emulsion as well as gel systems (Gordon Barbut, 1992; Nayak et al., 1998).

Conclusion

In the compositional and structural complexity of processed muscle foods, proteins have been identified as the components that play a most important role in water-binding, gelation, emulsification, meat particle-binding, and consistency in meat products. Physical and chemical processes of proteins involved in imparting desirable product functionality are influenced by various intrinsic and extrinsic (formulation and processing) factors. Various analytical tools are presently available for measuring functional properties of muscle proteins and meat products during processing and storage. To assure that results obtained from model system studies are applicable to meat processing, multiple processing factors that closely resemble those *in situ* conditions must be included in the experimental approach.

References

Acton, JC.; Ziegler, GR; Burge, Jr. DL. 1983. Functionality of muscle constituents in the processing of comminuted meat products. Critical Reviews in Food Science and Nutrition 18:99.

Asghar, A; Samejima, K; Yasui, T. 1985. Functionality of muscle proteins in gelation mechanisms of structured meat products. Critical Reviews in Food Science and Nutrition 22:27.

Barbut, S. 1995. Importance of fat emusification and protein matrix characteristics in meat batter stability. Journal of Muscle Foods 6:161.

Barbut, S. 1999. Use of a fiber optical probe to predict meat emulsion breakdown. (In press).

Barbut, S; Mittal, GS. 1988. Rheological and gelation properties of meat batters prepared with three chloride salts. Journal of Food Science 53:1296.

Bendall, JR. 1954. The swelling effect of polyphosphates on lean meat. J. Sci. Food Agric. 5:468.

Forrest, JC. 1998. Measuring pork quality. Proceedings of 51st Annual Reciprocal Meat Conference, Storrs, CT, p. 70.

Fukazawa, T; Hashimoto, Y; Yasui, T. 1961. Effect of some proteins on the binding quality of an experimental sausage. Journal of Food Science 26:541.

Galluzzo, SJ; Regenstein, JM. 1978. Role of chicken breast muscle proteins in meat emulsion formation: myosin, actin and synthetic actomyosin. Journal of Food Science 43:1761.

Gordon, A; Barbut, S. 1992. Mechanisms of meat batter stabilization: A review. Critical Reviews in Food Science and Nutrition 32:299.

Granicher, D; and Portzehl, H. 1964. The influence of magnesium and calcium pyrophosphates chelates of free magnesium ions, free calcium ions and free pyrophosphate ions on the dissociation of actomyosin in solution. Biochimica et Biophysica Acta 86:567.

Jones, KW. 1984. Protein-lipid interaction in processed meats, Proceedings of 37th Annual Reciprocal Meat Conference, Lubbock, TX, p. 52.

Kenney, PB; Kastner, CL; Kropf, DH. 1992. Muscle washing and raw material source affect quality and physicochemical properties of low-salt, low-fat, restructured beef. Journal of Food Science 57:545.

Lillford, PJ; Clark, AH; Jones, DV. 1980. In Water in Polymers, ACS Symposium Series No. 127, American Chemical Society, Washington, DC, p. 177.

Nayak, R; Kenney, PB; Slider, S; Head MK; Killefer, J. 1998. Cook yeild, texture and gel ultrastructure of model beef batters as affected by low levels of calcium, magnesium and zinc chloride. Journal of Food Science 63:945.

Offer, G; Trinick, J. 1983. On the mechanism of water holding in meat: the swelling and shrinking of myofibrils. Meat Science 8:245.

Parsons, N; Knight, P. 1990. Origin of variable extraction of myosin from myofibrils treated with salt and pyrophosphate. Journal of the Science of Food and Agriculture 51:71.

Robe, GH; Xiong, YL. 1993. Dynamic rheological studies on salt-soluble proteins from different porcine muscles. Food Hydrocolloids 7:137.

Siegel, DG; Schmidt, G.R. 1979. Ionic, pH and temperature effects on the binding ability of myosin. Journal of Food Science 44:1686.

Srinivasan, S; Xiong, YL. 1997. Sulfhydryls in antioxidant-washed beef heart surimi. Journal of Muscle Foods 8:251.

Torley, PJ; Young, OA. 1995. Rheological changes during isothermal holding of salted beef homogenates. Meat Science 39:23-34.

Xiong, YL. 1997. Structure-Functionality relationships of muscle proteins. In *Food Proteins and Their Applications*, Damoradan, S. and Paraf, A. (Eds.), Chapter 12, pp. 341-392. Marcel Dekker, Inc., New York, NY.

Xiong, YL; Blanchard, SP. 1993. Viscoelastic properties of myofibrillar protein and polysaccharide composite gels. Journal of Food Science 58:164.

Xiong, YL; Brekke, CJ. 1991. Gelation properties of chicken myofibrils treated with calcium and magnesium chlorides. Journal of Muscle Foods 2:21.

Xiong, YL; Decker, EA; Robe, GH; Moody, WG. 1993. Gelation of crude myofibrillar protein isolated from beef heart under antioxidative conditions. Journal of Food Science 58:1241.

Xiong, YL; Nole, DC; Moody, WG. 1999. Effect of pH and salt level on textural and sensory characteristics of low-fat beef sausages with added water and polysaccharides. Journal of Food Science (In press).