Factors Influencing Texture Formation in Comminuted Meats

Denise M. Smith*
Presenter

Introduction

Proteins are the principal functional and structural components of processed meats and determine the characteristic handling, texture and appearance of the products (Hermansson, 1985). Gelation, fat binding and water holding are the most important functional properties in cooked products. Heat-induced gelation is a two-step process which involves partial unfolding of protein followed by reaggregation into a cross-linked, three-dimensional network of protein fibers (Ferry, 1948). Fat and water are physically or chemically trapped inside the protein matrix. The binding of these components is related to the gel microstructure, which is ultimately influenced by the intrinsic properties of the protein and extrinsic factors such as environmental and processing conditions. Microstructural and rheological characteristics of the protein gel network formed are largely responsible for the texture, binding properties and cooking yield of comminuted products (Hermansson, 1985). Intrinsic protein properties which have been reported to influence functionality include total protein, distribution of protein between the various protein fractions (myofibrillar, stromal and sarcoplasmic) and type of muscle fiber. Extrinsic factors which influence protein functionality include pH, ionic strength, specific ions, cooking temperature and frozen storage. The role of several intrinsic and extrinsic factors on meat protein functionality has been reviewed recently (Smith, 1988; Whiting, 1988).

The overall objective of this poster display is to illustrate how intrinsic and extrinsic factors influence the functionality of proteins in the aqueous phase of meat batters and subsequently affect the texture and quality of the finished products. Frozen storage and deboning of meat is used as an example of the influence of extrinsic factors on protein functionality. The influence of intrinsic factors is illustrated by comparing the functionality of by-product proteins containing different percentages of sarcoplasmic, myofibrillar and stromal proteins. Only one example of each factor is illustrated, due to space constraints on the poster.

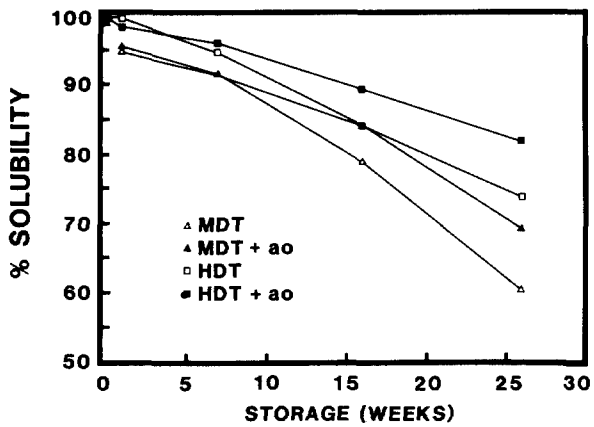
Extrinsic Factors

Frozen storage is one of the most important preservation methods for meat and meat products. Lower temperatures prevent or minimize many undesirable changes in meat, such as microbial growth and metabolic processes; however, some chemical reactions still occur which adversely affect product quality. Changes in texture, water-holding capacity, emulsifying capacity and cooking yields have been reported in several meat systems during frozen storage (Awad et al., 1969; Johnson, et al., 1974; Dhillon and Maurer, 1975; Sebranek et al., 1979). Functional changes during frozen storage of meat have been related to myofibrillar protein insolubilization (Yamamoto et al., 1977; Matsumoto, 1980; Wagner and Anon, 1986).

Part 1 of this poster presentation illustrates the influence of frozen storage and deboning on the functionality of hand deboned (HDT) and mechanically deboned (MDT) turkey meat when used in a cooked model system. Functional changes in turkey meat and in myofibrils isolated from the meat were determined during 26 weeks of frozen storage. Thiobarbituric acid (TBA) values in the stored meat were monitored to determine if lipid oxidation had any influence on functionality.

Lipid oxidation occurs extensively during the refrigerated and frozen storage of comminuted turkey meat (Dawson and Gartner, 1983) and may be one cause of myofibrillar protein denaturation (Buttkus, 1967; Jarenback and Liljemark, 1975). Lipid-protein interactions alter the functional properties of meat and may cause deleterious changes in final

Figure 1



Solubility (0.6M NaCl, pH 6.5) of myofibrils extracted from frozen, stored mechanically deboned (MDT) and hand deboned (HDT) turkey (MDT: mechanically deboned turkey with antioxidant; HDT: hand deboned turkey; HDT + ao: hand deboned turkey with antioxidant).

*D.M. Smith, Dept. of Food Science and Human Nutrition, Michigan State University, East Lansing, MI 48824

Reciprocal Meat Conference Proceedings, Volume 41, 1988.

Table 1. Characteristics of 3.5% (w/v) heat-induced myofibril gels prepared from stored, frozen (−20°C) hand deboned (HDT) and mechanically deboned (MDT) turkey.

Storage Time (Weeks)	Treatment	
	HDT	MDT
	Compressive Force to Failure (N)	
Unfrozen	5.54[a]	4.55[a]
1	5.71[a]	4.75[a]
7	4.22[b]	3.72[a]
16	2.83[c]	2.62[b]
26	1.30[d]	0.39[c]
	Syneresis (% of total protein solution)	
Unfrozen	19[a]	20[a]
1	24[b]	24[b,c]
7	27[b,c]	27[c]
16	27[b,c]	32[d]
26	30[c]	34[e]

[a-e]Means in the same column within compressive force or syneresis bearing a common superscript do not differ ($p<0.05$).

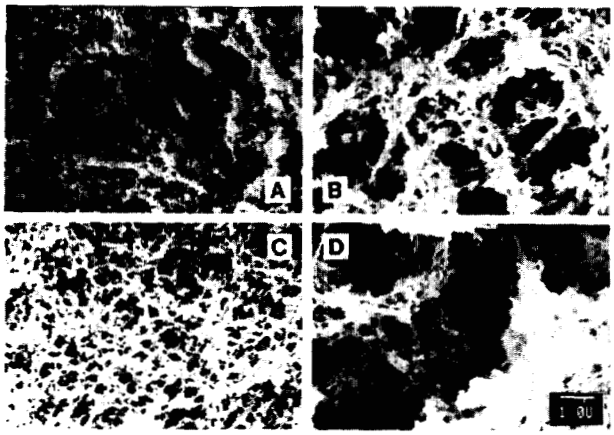
product quality (Sikorski, 1978). In this study, TBA values approached 5.0 mg malonaldehyde/kg meat by 26 weeks of storage, but lipid oxidation was not highly correlated with any of the functions properties evaluated.

Protein solubility in 0.6M NaCl decreased in all treatments with time (Fig. 1), probably indicating insolubilization/denaturation of meat proteins during frozen storage. Compressive force to failure decreased and syneresis of myofibril gels made from stored, frozen turkey meat increased with frozen storage time (Table 1). Changes in gel properties were correlated with changes in protein solubility (Table 2), indicating that insoluble proteins formed weaker gels with less water-holding ability. The microstructure of HDT and MDT gels prepared from unfrozen meat was filamentous and exhibited an open continuous matrix (Fig. 2) which is characteristic of strong gels with good water-holding capacity (Hermansson, 1985). After 26 weeks of frozen storage, the gels were more globular and lacked the regular, filamentous protein network. Large spaces occurred in the gels which were surrounded by highly aggregated protein networks. Microstructural changes were consistent with the objective changes observed in gel properties. Cooked yield in the meat model system decreased as time of frozen storage increased (Table 3) and was positively correlated to myofibril

Table 2. Correlation coefficients between model system test and gelation characteristics.

	Cooked Yield	Gel Syneresis	Compressive Force at Failure
Protein Solubility	0.60	−0.91	0.95
Compressive Force at Failure	0.61	−0.87	
Gel Syneresis	−0.59		

Figure 2



Scanning electron micrographs of heat-induced 3.0% (w/v) hand deboned (HDT) and mechanically deboned (MDT) turkey prepared from fresh and frozen meat: (A) HDT, unfrozen; (B) HDT, 26 weeks storage; (C) MDT, unfrozen; (D) MDT, 26 weeks storage. The bar represents 1 um.

solubility and gel properties.

Functional properties were also influenced by the deboning procedure. Myofibrils isolated from MDT became less soluble more quickly than HDT proteins. Gels made from MDT had lower failure forces than HDT throughout storage. HDT gels prepared from unfrozen meat contained thicker protein filaments in a slightly more irregular matrix than MDT gels.

Results of this study help illustrate the importance of meat protein gelation and water-holding ability on the characteristics of a comminuted meat product, as changes in isolated protein functionality correlated with changes in cooked meat yield. Results also indicate the importance of controlling frozen meat inventories. Research scientists studying basic biochemical and functional properties of meat proteins should monitor the length of time their samples are stored.

Intrinsic Factors

Gelation, water holding and fat holding are a function of the physicochemical or intrinsic properties of the proteins

Table 3. Cooked yield of model system frankfurters prepared from stored, frozen (−20°C) hand deboned (HDT) and mechanically deboned (MDT) turkey.

Storage Time (Weeks)	Cooked Yield (%)[a]	
	HDT	MDT
Unfrozen	92.8[b]	80.9[b]
1	90.9[b]	79.2[b]
7	88.2[c]	78.5[b]
16	84.4[d]	73.2[c]
26	84.3[d]	73.0[c]

[a]Cooked yield (%) = $\frac{\text{Wt. of meat after cooking}}{\text{Wt. of raw meat}} \times 100$

[b,c,d]Means in the same column bearing a common superscript do not differ (p 0.05).

Table 4. Proximate composition, protein distribution and timed emulsification of meat by-products.

Meat Type	pH	Moisture (%)	Fat (%)	Total Protein (%)	0.05M K Phosphate Soluble Proteins	0.6M NaCl Soluble Proteins	Insoluble Proteins	Modified Timed Emulsification[f]
					(Percent of Total Protein ± Standard Deviation)			mg protein/ml aqueous phase
Mechanically Deboned Chicken	6.59	65.6[a]	14.2[a]	17.4[a]	29.5 ± 1.4	41.0 ± 0.3	29.5 ± 0.9	10[a]
Beef Heart (Cap on)	6.21	66.5[b]	17.5[b]	15.4[b]	33.2 ± 1.7	20.1 ± 0.3	46.7 ± 0.4	>150[b]
Beef Lung (Lobes only)	6.60	79.7[c]	1.9[c]	17.7[a]	38.6 ± 0.1	9.4 ± 0.1	52.0 ± 0.9	>150[b]
Beef Spleen	6.40	79.9[c]	3.5[d]	15.3[b]	55.2 ± 1.7	20.5 ± 0.0	24.3 ± 0.9	20[c]
Pork Liver	6.28	71.7[d]	1.8[c]	22.1[c]	80.6 ± 1.9	12.6 ± 0.0	6.8 ± 1.2	40[d]
Pork Lung (Lobes only)	6.93	82.5[e]	2.0[c]	15.5[b]	53.8 ± 0.2	10.8 ± 0.4	35.4 ± 0.6	>140[b]

[a-e]Means in the same column bearing a common superscript are not significantly different ($p<0.05$).

[f]Timed emulsification is expressed as the lowest concentration of protein necessary to produce a stable cream layer after centrifugation.

present in the food system. Physicochemical properties are derived from a protein's amino acid sequence, secondary, tertiary and quaternary structure (Pour-El, 1981). Physicochemical properties include surface charge, sulfhydryl content, hydrophobicity, molecular weight, conformational stability and association/dissociation behavior (Kinsella, 1982; Wilding et al., 1984). Each meat protein has a characteristic set of physicochemical properties which determines the differences in functionality observed between the sarcoplasmic, myofibrillar and stromal proteins in comminuted products. Differences in the amount of total protein and percentage of the sarcoplasmic, myofibrillar and stromal fractions between different meat sources have necessitated the development of bind constants for use in sausage formulations. Least-cost formulation requires that a meat product be formulated using the least expensive meat sources which exhibit a satisfactory bind value when combined into the overall formulation. Many model system approaches to determine bind values have not been entirely satisfactory, although many tests have been developed (Carpenter and Saffle, 1964; Porteous, 1979; Regenstein, 1984).

Part 2 of the poster session illustrates the influence of protein distribution on meat by-product functionality in a comminuted meat model system.

The protein distribution varied among the by-products examined (Table 4). Mechanically deboned chicken contained at least twice the 0.6M NaCl soluble protein content of the meat by-products. The 0.6M NaCl soluble fraction probably was composed of myofibrillar proteins and some soluble collagen. Beef heart and beef lung contained the highest quantity of insoluble protein, while pork liver contained the highest quantity of 0.5M K phosphate soluble proteins. These insoluble protein fractions may be composed of stromal proteins or insoluble myofibrillar proteins.

The timed emulsification procedure of Perchonok and Regenstein (1986) was modified to evaluate meat by-products. A stable cream layer could not be formed using the recommended level of 5 mg protein/ml aqueous phase. The minimum protein concentration necessary to produce a stable cream after centrifugation was used as an index of protein

Table 5. Correlation coefficients between meat by-product protein distribution and model system properties.

	Modified Timed Emulsification	Reheat Yield	Compressive Force at Failure	Strain at Failure
0.05M K Phosphate Soluble Proteins	−.07	−.68	−.69	−.68
0.6M NaCl Soluble Proteins	−.71	.78	.80	.61
Insoluble Proteins	.72	.16	.14	.30
Strain to Failure	−.09	.63	.80	
Shear Force to Failure	−.35	.84		
Reheat Yield	−.41			

Table 6. Yield and textural characteristics of model system frankfurters prepared from mechanically deboned chicken and meat by-products (1:1 based on total protein content)[e].

Meat Type	Batter pH	Cooked Yield (%)	Reheat Yield (%)	Compressive Force at Failure (N)	Strain at Failure
Control[f]	6.6	91.0[a]	82.1[a]	11.86[a]	0.53[a]
Beef Heart	6.5	92.8[a]	79.3[b]	11.74[a]	0.53[a]
Beef Lung	6.6	93.1[a]	79.1[b]	5.63[b]	0.51[ab]
Beef Spleen	6.6	94.0[a]	74.0[c]	3.45[cd]	0.41[c]
Pork Liver	6.5	91.4[a]	74.4[c]	2.73[d]	0.45[c]
Pork Lung	6.8	92.9[a]	68.0[d]	4.18[cd]	0.52[ab]

[a-d]Means in the same column bearing a common superscript are not significantly different ($p>0.05$).

[e]Batter formulation: 12% protein, 30% fat, 54% moisture and 2% salt.

[f]Control was composed of 100% mechanically deboned chicken.

functionality among the by-products. Changes in the modified timed emulsification test were positively correlated with the quantity of by-product insoluble proteins and negatively correlated with the quantity of 0.6M NaCl soluble proteins (as 0.6M NaCl soluble proteins increased, less protein was needed to form a stable cream layer) (Table 5). The modified timed emulsification test was not highly correlated with any parameters measured in the model system frankfurter test.

Reheat yield, compressive force at failure and strain at failure of model system frankfurters were influenced by meat by-product protein composition (Table 6). Reheat yield was positively correlated with the quantity of 0.6M NaCl soluble proteins and inversely correlated with 0.5M K phosphate soluble proteins. Compressive force and strain at failure of the model system frankfurters were negatively correlated with 0.05M K phosphate soluble proteins and positively correlated with 0.6M NaCl soluble proteins. The salt-soluble myofibrillar proteins are generally considered to impart the most functionality to processed meats. In this study, larger quantities of the 0.6M NaCl soluble proteins were related to larger reheat yields and better textural properties in the model system frankfurters. The quantity of insoluble proteins in the meat by-products was not strongly correlated with the parameters measured in the frankfurters.

Results indicate that the protein distribution of meat by-products was related to the bind and texture imparted to comminuted meat products. With further study, this information may have application to least-cost formulation calculations, as it is possible that a certain percentage of salt-soluble proteins or ratio of protein fractions are necessary to produce the desired bind in a sausage formulation.

Materials and Methods

Part I. Changes in Deboned Turkey due to Frozen Storage (See Smith, D.M. 1987, J. Food Sci. 52:22 for more details.)

Materials and Sample Preparation. Fresh, unfrozen MDT and HDT was obtained from a local processor. HDT was composed of 60% white meat and 40% dark meat. MDT was obtained from turkey racks using a Beehive deboning machine. Both deboned products contained skin. Treatments were (1) HDT, (2) hand deboned turkey meat with antioxidant (HDT + ao), (3) MDT, and (4) mechanically deboned turkey with antioxidant (MDT + ao). Tenox 2 antioxidant (Eastman Kodak) was added at 0.02% of the fat content. Tenox 2 contains butylated hydroxyanisole, propyl gallate and citric acid. Batches were prepared in triplicate. Meat was packaged in 450g aliquots in mylar-polyethylene film, analyzed at 1 day (unfrozen) or frozen at −20°C and analyzed after 1, 7, 16 and 26 weeks of storage. Proximate composition was determined by AOAC (1984) procedures.

Preparation of myofibrils. Myofibrils were isolated in 0.1M NaCl, 0.05M K phosphate buffer, pH 7.0 as described by Smith and Brekke (1985). The final myofibril pellet was solubilized in 0.6M NaCl, ph 6.5 to obtain a concentration of 30 mg protein/ml buffer.

Protein Solubility. Solubility was determined in 0.6M NaCl, pH 6.5 by centrifuging the myofibril protein solution at 10,000 × g for 10 min.

Gelation characteristics. Gels were prepared by heating 40 mL of the myofibril solution in covered 50 mL centrifuge tubes for 30 min at 70°C. Syneresis after gel formation was determined by measuring the volume of free liquid removed from the tubes with a Pasteur pipet. Gels were equilibrated to 20°C and cut cross-wise into 2.0 cm (height) × 2.5 cm (diameter) cylindrical pieces. An Instron Universal Testing Machine (Model 4202, Canton, MA) was used to compress gels between two flat parallel surfaces at a crosshead speed of 1cm/min. Gels were prepared for scanning electron microscopy as described by Yasui et al. (1979) and observed with a JEOL scanning microscope (Model JSM-35C) at an accelerating voltage of 15 KV.

Meat cook test. About 10g turkey meat containing 2.0% NaCl was blended for 3 min at a speed setting of 3 using a Sorvall Omni-Mixer. The meat was cooked for 30 min in a 70°C water bath.

Part II. By-Product Functionality

Materials. Mechanically separated chicken was purchased from Nottawa Gardens Corp., Athens, MI. By-products were obtained from five young market weight hogs and steers processed at the MSU Meats Laboratory. By-products

were ground sequentially through the 10, 6 and 3 mm plate of a Hobart grinder (Model A-200), vacuum packaged and frozen until used within three months. Proximate composition was determined by AOAC (1984) procedures.

Timed Emulsification. Timed emulsification was performed as described by Galluzzo and Regenstein (1978) with modifications. The lowest concentration of protein required to produce a stable cream layer after centrifugation at 30,000 × g for 15 min was recorded.

Quantitation of Protein Functions. A weighed portion of meat was blended for 1 min with 4 volumes of 0.05M Na phosphate buffer, stirred for 3 hr and centrifuged at 23,000 × g for 15 min. The supernatant was saved and the residue re-extracted for 1 hr. Following centrifugation, the supernatants (containing the 0.05M K phosphate soluble proteins), were combined and quantitated. The precipitate was mixed with 4 volumes of 0.6M NaCl, 0.05M K phosphate, pH 7.4 and extracted twice as described above. The supernatants, designated 0.6M NaCl soluble proteins, were combined and quantitated. The precipitate was weighed and designated insoluble proteins. The protein content of each fraction was determined by Kjeldahl (AOAC, 1984).

Model System Frankfurters. Frankfurter batter was prepared using a silent cutter as described by Smith and Brekke (1984), except that the batter was stuffed into 50 ml conical centrifuge tubes, capped, and heated in a 75°C water bath to an internal temperature of 72°C. Formulations were prepared using a 50:50 blend (based on the protein content of the meats) of MDC and meat by-product. Formulations were standardized to 56% moisture, 30% fat, 12% protein and 2% salt by the addition of pork back fat or ice. Strain and compressive force at failure were measured on a 1.5 × 1.5 cm core using an Instron (Model 4202) at a crosshead speed of 10 mm/min with a 50 N load cell. Reheat yield was calculated after heating a 20g core in 100 ml of 95°C water for 10 min.

References

AOAC 1984. "Official Methods of Analysis," 14th ed. Association of Official Analytical Chemists, Washington, DC.

Awad, A.; Powrie, W.D.; Fennema, O. 1969. Deterioration of freshwater muscle during frozen storage at −10°C. J. Food Sci. 34:1.

Buttkus, H. 1967. The reaction of myosin with malonaldehyde. J. Food Sci. 32:432.

Carpenter, J.A.; Saffle, R.L. 1964. A simple method of estimating the emulsifying capacity of various sausage meats. J. Food Sci. 29:774.

Dawson, L.E.; Gartner, R. 1983. Lipid oxidation in mechanically deboned poultry. Food Technol. 37(7):112.

Dhillon, A.S.; Maurer, A.J. 1975. Stability study of comminuted poultry meats in frozen storage. Poultry Sci. 54:1407.

Ferry, J.D. 1948. Protein gels. Adv. Prot. Chem. 4:1.

Hermansson, A.M. 1985. Water- and fat-holding. In "Functional Properties of Food Macromolecules," ed. J.R. Mitchell and D.A. Ledward, p. 273. Elsevier Appl. Sci. Pub., New York.

Jarenback, L.; Liljemark, A. 1975. Ultrastructural changes during frozen storage of cod. III. Effects of linoleic acid and linoleic acid hydroperoxides on myofibrillar proteins. J. Food Technol. 10:437.

Johnson, P.G.; Cunningham, F.E.; Bowers, J.A. 1974. Quality of mechanically deboned turkey meat: Effect of storage time and temperature. Poultry Sci. 53:732.

Kinsella, J.E. 1982. Protein structure and functional properties: Emulsification and flavor binding effects. In: "Food Protein Deterioration – Mechanisms and Functionality," ed. J.P. Cherry, ACS Symposium Series 206, p. 301. Am. Chem. Soc., Washington, DC.

Matsumoto, J.J. 1980. Denaturation of fish muscle proteins during frozen storage. In: "Chemical Deterioration of Proteins." (Ed.). J.R. Whitaker and M. Fujimaki, p. 205. Am. Chem. Soc., Washington, DC.

Perchonok, M.H.; Regenstein, J.M. 1986. Stability at comminution chopping temperatures of model chicken breast muscle emulsions. Meat Sci. 16:17.

Porteous, J.D. 1979. Some physico-chemical constants of various meats for optimum sausage formulation. Can. Inst. Food Sci. Technol. J. 12:145.

Pour-El, A. 1981. Protein functionality: Classification definition and methodology. In: "Protein Functionality in Foods." ed. J.P. Cherry, ACS Symposium Series 147, p. 1. Am. Chem. Soc., Washington, DC.

Regenstein, J.M. 1984. Protein-water interactions in muscle foods. Proc. Recip. Meat Conf. 37:44.

Sebranek, J.G.; Sang, P.N.; Topel, D.G.; Rust, R.E. 1979. Effects of freezing methods and frozen storage on chemical characteristics of ground beef patties. J. Anim. Sci. 48:1101.

Sikorski, Z.E. 1978. Protein changes in muscle foods due to freezing and frozen storage. Int. J. Refrigeration 1:74.

Smith, D.M. 1987. Functional and biochemical changes in deboned turkey due to frozen storage and lipid oxidation. J. Food Sci. 52:22.

Smith, D.M. 1988. Meat Proteins: Functional properties in comminuted meat products. Food Technol. 42(4):116.

Smith, D.M.; Brekke, C.J. 1984. Functional properties of enzymatically modified beef heart protein. J. Food Sci. 49:1525.

Smith, D.M.; Brekke, C.J. 1985. Enzymatic modification of the structure and functional properties of mechanically deboned fowl proteins. J. Agric. Food Chem. 33:631.

Wagner, J.R.; Anon, M.C. 1986. Effect of frozen storage on protein denaturation in bovine muscle. 1. Myofibrillar ATPase activity and differential scanning calorimetric studies. J. Food Technol. 21:9.

Whiting, R.C. 1988. Ingredients and processing factors that control muscle protein functionality. Food Technol. 42(4):104.

Wilding, P.; Lifford, P.J.; Regenstein, J.M. 1984. Functional properties of proteins in foods. J. Chem. Tech. Biotechnol. 34:182.

Yamamoto, K.; Samejima, K.; Yasui, T. 1977. A comparative study of changes in hen pectoral muscle during storage at 4°C and −20°C. J. Food Sci. 42:1642.

Yasui, T.; Ishioroshi, M.; Nakano, H.; Samejima, K. 1979. Changes in shear modulus, ultrastructure and spin-spin relaxation times of water associated with heat-induced gelation of myosin. J. Food Sci. 44:1201.