

# SECTIONED AND FORMED MEAT

by

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Various procedures are available for preparing meat products that have the appearance and consistency of intact muscle meat, but that are composed of meat pieces that cohere together. These pieces of meat may be fine flakes of frozen and tempered meat or they may, at the other extreme, be entire muscle systems. The cohesive substance that binds the pieces together can vary from emulsion systems to extracted myofibrillar proteins.

Additives that affect the binding strengths between particles are salt, phosphate, soy products, dairy powders, and enzymatic tenderizers. Frictional, impact and ultrasonic energy can also be applied to the meat so as to enhance the particle cohesion. Equipment for manipulation of the meat pieces varies widely in design, duration of operation and cost. These are some of the topics that I will discuss in this presentation. I will discuss the general topics of basic research on meat rolls as well as on tumbling and massaging as related to the development and production of sectioned and formed meats.

A considerable amount of work has been done on binding properties of muscle protein gels and emulsion systems. Fukazawa *et al.* (1961a, 1961b and 1961c) reported the importance of salt-soluble proteins for binding in emulsified sausages. Swift *et al.* (1961), Hansen (1960), and Mauer *et al.* (1969) have demonstrated that the water-soluble proteins contribute little to the emulsifying capacity of meats when compared to the salt-soluble proteins. Nakayama and Sato (1971a,b,c) support these findings by using a coaxial cylinder type viscometer to measure the viscoelasticity of the heat coagulated gels from myofibrillar protein solutions differing in protein content, suggesting that these values can be used as indices for comparing binding qualities in meats.

Schnell *et al.* (1970) and Vadehra and Baker (1970) theorized that the binding of meat proteins as well as the emulsification of meat proteins play important roles in developing a satisfactory texture in both meat emulsions, such as frankfurters, and

ground-meat sausage, such as salami. Sato and Nakayama (1970) also studied the rheological properties of minced meats and established that the binding quality of meat is the most important index for measuring the quality of the product. From information available in the literature on emulsion and comminuted meats, as well as chunk type products, the mechanism of binding in these systems depends upon similar protein functionality. Meat emulsions are, however, a more heterogenous system consisting of genuine solution, gel solution, suspension, emulsion and form (Kotter and Fischer, 1975). The actual composition of an emulsion product may vary from, mainly, a true emulsion to almost, totally, a suspension of meat particles (Theno and Schmidt, 1978).

Schnell *et al.* (1970) and Vadehra and Baker (1970) describe the binding between chunks of meat as a heat mediated reaction, since in the raw form meat does not show binding to any extent. This binding is affected by water binding, cell disruption, releasing of the intracellular material, and the physical and chemical changes in all of the muscle proteins on heating. The salt-soluble proteins become highly concentrated between the chunks of meat (Schnell *et al.* 1970; Vadehra and Baker, 1970; Siegel *et al.* 1978a,b). The binding between chunks of meat is concluded to be the result of structural rearrangement of the salt-soluble proteins (Hansen *et al.* 1966; Vadehra and Baker, 1970; Kotter and Fisher, 1975; Theno *et al.* 1978c). It appears that previously dissolved salt-soluble proteins are oriented on meat surfaces before and during the heat initiated binding phenomenon.

Macfarlane *et al.* (1977) compared the ability of myosin, actomyosin and sarcoplasmic proteins to bind pieces of meat together. When myosin was added between pieces of meat that had not been previously subjected to mechanical agitation, it was able to bond the meat pieces to each other at salt concentrations of 0.2-1.4M. Actomyosin was found to match myosin in this respect only at high salt concentrations of 1.2-1.4M. The addition of sarcoplasmic proteins to the myosin binder, enhanced binding at no added salt, did not affect it at 0.2M salt and decreased it at high salt concentrations. Sarcoplasmic proteins, themselves, exhibited no binding ability.

Several methods of measuring binding between

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chunks of meat have been developed. Panel evaluation (Acton, 1972a,b), breaking force of meat rolls (Pepper and Schmidt, 1975), breaking force of slices (Siegel *et al.* 1978a), and tensile strength between two meat particles (Macfarlane *et al.*, 1977) are methods that were aimed at determining the particle to particle cohesion in sectioned and formed meat products.

#### *Meat Rolls*

Agglomeration of meat particles into a single meat mass or roll by mechanical agitation has been utilized for several years. The agitation or tumbling of meat particles in the presence of a salt solution brings the salt-soluble proteins to the meat surface. These tacky proteins interact and coagulate during heating to bond the meat surfaces (Woollen, 1971). Salt not only aids meat particle binding, but also reduces fluid loss during heating (Wierbicki *et al.*, 1957) Froning (1966) found that polyphosphates significantly increased poultry meat binding strength. Acton (1972a) reported significant increases in cooking loss as internal temperature of poultry loaves increased above 55°C. Binding strength of these poultry loaves also increased as the internal temperature increased in the range from 35-82°C. Acton (1972b) also reported significant decreases in cooking loss along with increases in binding strength as meat particle size became smaller. Acton and McCaskil (1972) found the salt-soluble rather than the water-soluble proteins in poultry meat are responsible for increased meat binding and cooking yield.

Schnell *et al.* (1970) demonstrated that the addition of salt increased the cook yield in poultry loaves and also that salt and polyphosphates increased binding in the loaf slices. Pepper and Schmidt (1975) found that for both salt and salt-phosphate treated beef rolls, the highest cook yield occurred at an internal temperature of 68°C. These authors also found greater cook yields and binding strengths from the salt-phosphate treated rolls rather than the salt-treated rolls. Both hot-boned and cold-boned beef rolls with salt-phosphate treatment displayed higher binding strengths and cook yields than corresponding salt treated rolls. The rolls prepared from hot-boned beef gave higher cook yields but lower binding strengths in both salt-phosphate and salt treatments than did the rolls prepared from cold-boned beef.

Kardouche *et al.*, (1978) used four levels of soy protein isolate with pre- and post-rigor pectoralis muscles of turkeys. Water was added equal to three times the weight of the isolate. As the level of isolate increased, the flavor, tenderness texture and accept-

ability scores increased, and the shear values decreased. Level of protein isolate had a greater influence on the shear values than the rigor state of the meat. Rolls made from pre-rigor muscle had higher cooked yields than those made from post-rigor muscle.

Moore *et al.*, (1976) prepared beef rolls with coarse-ground beef, 8% added water and either salt, salt plus 0.25% sodium tripolyphosphate, soy isolate, textured soy protein and modified whey solids at 1,2 and 3% levels. Binding strength increased as salt content increased from 1% to 3%. Cook yield increased from 79% with 1% salt to 93% with 3% salt. The addition of tripolyphosphate resulted in increased binding strength and cook yields. The modified whey solids at 2% level had the highest binding strength and soy isolate had the highest cook yield of the non-meat protein materials added.

Ockerman and Crespo (1977) evaluated organoleptic properties of roasted fabricated beef products. Panel members gave higher scores for the sliced fabricated product served on buns than when evaluating meat only. The product was more palatable when cooked with foil caps to 60° final internal temperature. This type of product has been shown to be of acceptable microbial quality Dennis *et al.*, (1972).

#### *Flaked, Formed and Sectioned*

Mandigo (1974, 1975) reviewed the work at the University of Nebraska on the restructuring of pork. This group studied the effect of mixing time (Belohlavý and Mandigo, 1974), grinding versus flaking (Chesney and Mandigo, 1973), salt content and flaking temperature (Mandigo *et al.*, 1973), flake size (Popenhagen, 1973), tripolyphosphate and salt (Neer and Mandigo, 1974a, Schwartz and Mandigo, 1974), frozen storage (Neer and Mandigo, 1974b, 1977), pre-chill flaking (Hansen and Mandigo, 1972) as well as portion thickness and cooking temperature (Campbell *et al.*, 1977). Vandover and Yaiko (1977) utilized soy concentrate in the formula of flaked, formed and sectioned pork chops.

Cross and Stanfield (1976) reported on consumer evaluation of restructured beef steaks. Consumers showed the greatest preference for the restructured beef steaks with 30% fat and added salt. Field *et al.*, (1977) determined that restructured beef steaks containing 5% mechanically deboned meat have improved quality. Ford *et al.*, (1978) utilized suspensions of crude myosin, sarcoplasmic protein and a mixture of both to bind coarsely ground beef into restructured steakettes.

Farrington (1975) described the production of flaked, formed and frozen lamb products. Moore (1978) describes the production of fabricated bacon that contains soy isolate.

*Sectioned and Formed*

More than 284 million pounds of sectioned and formed hams were produced under federal inspection in 1977. This accounted for almost 19% of the federally inspected ham production (Anonymous, 1978). Numerous patents have been granted on the procedures and equipment used to produce sectioned and formed meat (Table 1). This information is included so that the reader may seek additional detail if desired.

Trade journals have included articles on the procedures used in tumbling and massaging hams as well as the advantages and disadvantages of the procedure. (Gallert, 1971; Anonymous, 1977; Woollen, 1971; Anonymous, 1971; Weiss, 1974; Michels, 1976; Ingenpass, 1973; Flores, 1976; Michels *et al.*, 1972; Michels, 1973; Schmidt, 1977).

Some of the advantages of tumbling and massaging are:

1. The processor is able to create products of desired uniform shape, weight and sliceability.
2. Meat becomes pliable and is therefore easily handled by machine.
3. The consumer can be presented with a uniform product of controlled composition.
4. Shrinkage and cooking losses can be controlled.
5. Muscle tissue from any part of the animal may be utilized to form cuts that resemble primal cuts.
6. Color can be made more uniform.
7. Tenderness can be increased.
8. Uniformity of additive concentration and distribution can be improved.

All of these advantages can be achieved, but the processor must remember the limitations that may determine whether the sectioned and formed products produced will be accepted:

1. It will not improve low quality meat. Connective tissue will remain relatively undisturbed and objectionable. Fat must be removed or it will show up in a very undesirable way in the sliced product. Fresh meat with a low bacteria count will

TABLE 1

**A PARTIAL LIST OF PATENTS PERTAINING TO SECTIONED AND FORMED MEAT**

Bard, J. C., Olson, F. C., Oscar Mayer and Co., Madison, WI U.S. Patent 3,679,434 (1972) Mechanical agitation and injection of polyphosphate salts into large portions of meat to form consolidated meat bodies.

Fuger, I. L., Drobyshev, A. S., Osadchaya, E. I., Stopchik, R. S. USSR Patent 544,418 (1977) Method of preparing a pork product by brine injection, kneading, immersion and rekneding. Food Sci. and Tech. Abs. 9:851494

Hawley, R. L., Tuley, W. B., Ralston Purina Co., St. Louis, MO U.S. Patent 3,989,851 (1976) Method of protein fortification of extra pumped meats.

Jespersen, K., Engman, T. E. U.S. Patent 4,038,426 (1977) Massaging in pickle. Food Sci. and Tech. Abs. 10:1543

Langen, C. P., H. J. Langen & Sons, Ltd., Rexdale Canada U.S. Patent 4,029,824 (1977) A rotary tumbling device with penetrating means in the chamber.

Mauer, J. E., Gerlando, B., deZartic Frozen Meat Inc. U.S. Patent 3,999,248 (1976) Apparatus and method for knitting proteinaceous fragments into a unified mass. (e.g. patties or cube steak). Food Sci. and Tech. Abs. 9:751343

Litovko, V. I., Petrovich, V. A., Kabaldin, G. S., Bulikov, S. I. USSR Patent 544412 (1977) Use of pressure, ultrasound and vibration to increase brine uptake. Food Sci. and Tech. Abs. 9:751342.

Maas, R. H., Oscar Mayer and Co., Chicago, IL U.S. Patent 3,076,713 (1963) Mechanical working of whole pieces of meat of at least one-half pound to cause a tacky exudate on its surface.

McGowen, R., Ralston Purina Co., St. Louis, MO U.S. Patent 3,503,755 (1970) Incising dark poultry meat pieces to form slits through the muscle sheaf and mixing of these incised pieces with a binder matrix.

Olson, F. C., Padebradsky, E., Oscar Mayer and Co., Madison, WI U.S. Patent 3,649,300 (1972) Method of preparing a meat product having a texture similar to that of a primal cut and high polyunsaturated fat content.

Schlamb, K. F., Calgon Corp., Pittsburgh, PA U.S. Patent 3,499,767 (1966) Methods of binding large pieces of poultry using mechanical agitation, salt and phosphate.

Sommer, H. West German Patent Application 1 911 602 (1970) Apparatus for preparing meat for subsequent treatment. Describes a ham tumbler. Food Sci. and Tech. Abs. 3:85901.

Torr, D., Cheyney, PA U.S. Patent 3,024,113 (1962) Utilize an emulsion of poultry by-products such as giblets, skin, hearts, livers, etc. to act as a binder for pieces of meat in the manufacture of cold cuts.

Torr, D., Ralston Purina Co., St. Louis, MO U.S. Patent 3,173,795 (1964) Use of fibrous raw animal by-products to bind meat chunks together.

Torr, D., Oyster Bay, NY U.S. Patent 3,268,339 (1966) The use of uncooked dark meat of the poultry leg or thigh and/or giblets along with fiberformed skin as a binder of boneless meat.

Torr, D. Ralston Purina Co., St. Louis, MO U.S. Patent 3,276,880 (1966) Proteolytic digestion and salt treatment of comminuted poultry and/or animal byproducts and mixtures thereof to form a pasty mass utilizable as a binder matrix for chunks of raw meat after cooking.

Vogel, P. W., Bird Provision Co., Pekin, IL U.S. Patent 3,677,775 (1972) Hot boning, grinding and shaping of meat products.

Verurg, D. L. U.S. Patent 4,036,997 (1977) Uses freeze expansion to compress tacky meat in a mold. Food Sci. and Tech. Abs. 10:1542.

Wilcox, J. C., Hafstad, M. J. Armour and Co., Chicago, IL U.S. Patent 3,497,361 (1970) British patent 1,116,294 (1968) Fraying the surfaces of small chunks of meat in the presence of mechanical agitation with metallic salt so that the resulting product has the appearance of a coherent body of intact meat.

produce a finished product with good appearance and shelf life. Color uniformity will be improved, but wide differences in muscle color cannot be modified sufficiently to produce an attractive product.

2. It does require a sizeable investment in equipment. For some products a paddle or ribbon blender can be used, but for most operations a tumbler or massager is preferred. These are usually purchased, but some meat companies are reported to be manufacturing their own.
3. Management must be set up for product quality control, production supervision and marketing of the final product.

Now we can define the processes and look at the results from both the applied and basic sides.

Tumbling generally refers to placing meat in a stainless steel drum that has baffles on the inside. Some processors indicate that the drum should rotate at a speed such that the meat is carried to the top of the drum and drops down at least three feet to the meat at the bottom of the drum. This impact of meat on meat as well as the friction of one portion abrading another portion has several functions. It aids in abrading the myofibrillar proteins from the surface of the meat, but only in skinned, boned and defatted meat products. It also makes the meat more pliable and increases the rate of cure distribution. The only reason to tumble bone-in products is to aid the distribution of the cure. Generally this is not necessary to do if a good multi-needle stitch pump or artery pump is used properly.

Many of the tumblers are of the batch cement mixer type. A large unit that originated in the Netherlands uses an intermittent tumbling of a series of containers hooked to a chain. This system also uses needles or bars to abrade and penetrate the surface of the meat so as to encourage absorption of the brine and scrape bits of muscle into the liquid.

Massaging is generally a less severe treatment than tumbling. The massagers come in many sizes and designs. Most industrial models use a bin similar to a standard meat vat. A large motor is geared down to power a vertical shaft that has arms attached to it. Some equipment companies use arms that are square in cross section while others use a dull propeller shaped arm.

A massager is actually a slow mixer designed to gently stir the large chunks of meat. A mixer does the job very well for small pieces of meat that have

been ground, but most mixers tear large pieces of meat to bits, or, else the large chunks are pierced by the paddles and inhibit the effectiveness of the mixing action.

Regardless of the system you use, you should be certain that the machine is manipulating all the pieces of meat. The speed of revolution should be checked for each machine and one or two hams should be labeled to ensure that they are all being stirred well. However, make sure you can retrieve your tag or label.

Rahelic *et al.*, (1974) systematically studied the effect of tumbling and massaging on pasteurized canned hams. Massaging for up to 320 minutes decreased released juice in the cans while prolongation beyond 460 minutes increased it. Tenderness was similarly affected. Tumbling had similar effects. Histologically, increased duration of tumbling caused a swelling and loosening of the structure of the sarcomeres. After extensive tumbling, the sarcomere structure degraded completely. Actin filaments and Z discs were most rapidly broken down.

Workers in our laboratory have investigated the changes that occur in cured porcine muscle during massaging. Theno *et al.*, (1978a) collected samples of rectus femoris from cured ham muscles which had been massaged for 0, 1, 2, 4, 8 or 24 hours with 0, 1, 2, or 3% of added salt in the presence or absence of 0.5% phosphate for examination with a scanning electron microscope (SEM). After several hours of massaging, fiber disruption became evident. Further massaging resulted in longitudinal disruption of the fibers. Myofibrils were observed to separate and shred from the surface of the fibers. After 24 hours of massage, all treatments showed massive fiber disruption and loss of normal structural integrity. The effects of massaging were more pronounced in the presence of salts and phosphates at all time intervals.

Samples of the tacky exudate formed on meat surfaces as a result of massaging muscle in the presence of salt and/or phosphate were removed at intervals during 24 hours of massaging and observed using a light microscope. Samples without added salt or phosphate showed broken fibers and fragments from fiber disruption. Samples with salt or phosphate showed both solubilized protein and fragments from fiber disruption. Samples with salt and phosphate showed primarily clouds of solubilized protein. Length of massaging enhanced the effects in all samples. (Theno *et al.*, 1978b)

Samples of the binding junction were removed from cooked ham rolls which had been stuffed at

intervals during 24 hours of massaging in the presence of varying levels of salt (0, 1, 2 and 3%) and phosphate (0 and 0.5%) and examined using a light microscope to determine the microstructural characteristics of junctions exhibiting good and poor binding characteristics. Junctions in low salt rolls (<2%) were filled with fat and cellular fragments. Junctions from rolls with adequate salt (>2%) and phosphate (0.5%) exhibited good binding characteristics. These junctions were composed of aligned areas, and emulsion-like areas. Junctions from high salt and phosphate rolls showed a high degree of junction alignment and exhibited optimal binding characteristics. (Theno *et al.*, 1978c)

Samples of the tacky exudate formed on the meat surfaces were also removed at time intervals and analyzed for fat, moisture and protein. Results showed that as the massaging time increased, the percentage of fat and protein in the exudate increased in all treatments. The binding quality and cooking loss of the prepared ham rolls were also improved by the massaging process. A salt treatment of 2% appeared to be optimal for the development of adequate binding with decreased cooking loss. It was found that the presence of phosphate and absence of massaging resulted in the production of a product exhibiting cooking loss and binding properties superior to those of a product prepared in the absence of phosphate and presence of massaging, although the presence of both massaging and phosphate is beneficial for the production of an overall superior product. (Siegel *et al.*, 1978a)

The samples of the tacky exudate were also analyzed by SDS polyacrylamide gel electrophoresis to determine the relative percentage of various myofibrillar proteins present. The results showed that phosphate exerts the greatest effect on the relative percentages of actin, myosin and tropomyosin, and its action occurs primarily on meat surfaces before the massaging process is initiated. The massaging process involves great degrees of tissue destruction at the cellular level which aids in the extraction, solubilization, concentration and distribution of the major myofibrillar proteins on surfaces and in interiors of muscle chunks, which is beneficial in the improvement of binding. (Siegel *et al.*, 1978b).

Krause *et al.*, (1978a) determined that tumbling significantly improved canned ham external appearance, color, sliceability, taste, aroma and yield. Three-hour continuous tumbling resulted in less improvement in product quality and yield than did 18-hour intermittent tumbling. The addition of sodium tripolyphosphate and removal of most fat cover resulted

in better sliceability and yield. Ockerman *et al.*, (1978) determined that tumbling for 30 minutes did not increase yield, texture or sensory characteristics of canned hams.

Krause *et al.*, (1978b) found that sodium tripolyphosphate and tumbling independently increased the migration of salt and nitrite and resulted in an increase in color development. Dzoljic *et al.*, (1976) determined that subjecting ham to reduced pressure during mechanical kneading promoted nitrosomyoglobin formation and nitrite breakdown and resulted in improved organoleptic quality. Zayas *et al.*, (1976) showed that vacuum accelerates salt distribution in hams. Rejt *et al.*, (1978) determined that vacuum massage improved tenderness and water holding capacity of hams.

Recently, a number of innovations have been applied to sectioned and formed meats. Hawley (1977) discussed the use of isolated soy protein in sectioned and formed ham. Our group at the University of Illinois has work under way on this product. Huffman and Cerdray at Auburn University (Anonymous, 1978) developed a process that involves blending chunked and wafer-sliced meats to promote release of natural binding proteins, forming the mixture into logs for freezing and tempering before pressing into shape and slicing into steaks and chops. The chunks of meat were tenderized four times with a blade-tenderizer before being mixed with a wafer sliced portion of meat.

Reynolds *et al.*, (1978) determined that meat when subjected to ultrasonic vibrations during mixing had increased particle to particle cohesion. Ultrasound caused changes in muscle microstructure, decreased cooking loss and increased extractability of salt-soluble protein. Thiemig and Sielaff (1977) studied the effects of ultrasonic treatment on meat consistency.

### Summary

A considerable amount of work has been done on binding properties of muscle protein gels and emulsion systems. This information may be partially applicable to the heat-mediated binding between chunks of meat since the actual composition of an emulsion product may vary from, mainly, a true emulsion to almost, totally, a suspension of meat particles. Previously dissolved salt-soluble proteins are oriented on meat surfaces before and during heat initiated binding.

Myosin binds pieces of meat together well. Binding is enhanced by increased extraction of myosin by the

use of salt, phosphate and mechanical agitation. The addition of non-meat proteins has a variable effect on particle cohesion which depends on the specific protein used, its properties and the manner in which it is added.

Flaked, formed and sectioned pork, beef and lamb products are produced. Connective tissue, fat and mechanically deboned meat can be used in these restructured products with adequate palatability results.

Almost 19% of the federally inspected ham in the United States is sectioned and formed. Numerous patents exist on procedures and equipment involved in the production of sectioned and formed meat.

Tumbling generally refers to placing meat in a stainless steel drum that has baffles on the inside. Impact and friction act to promote protein extraction to form an exudate, increase pliability and enhance the rate of cure dispersion.

Massaging is a more gentle stirring of meat chunks to utilize abrasion and pressure to extract protein, increase pliability and enhance cure distribution. Appropriate levels of salt and phosphate increase cooking yields and cohesion of tumbled or massaged products.

The application of mechanical energy solubilizes proteins and disrupts myofibrils. The proteins coagulate and realign during cooking to bind chunks of meat together.

Canned ham external appearance, color, sliceability, taste and yield are improved by tumbling or massaging.

Recent innovations of blending wafer-sliced meats with meat chunks to simulate roasts and steaks, of using ultrasound to increase binding and of using protein extracts as binders should provide interesting results in the future.

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