# PROCESSING OF MEAT TO MEET CONSUMER DEMAND: DEVELOPMENTS IN RESTRUCTURED AND LOW-FAT PROCESSED PRODUCTS

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### *Summary*

*One of the many goals for processed meat products now and in the immediate future is to respond to the need for lower-fat and low-fat products. Regardless how the goal is met, success will come only if the following facts are kept in sharp focus. The products must be perceived as* ***healthy****, a* ***good economic value****, have* ***outstanding flavour*** *and have* ***outstanding palatability****. The dietary goal will continue to be to* ***consume no more than 30% of the total calories/day as fat and limit saturated fat to 10% of the total calories****.*

*The problem centres on reducing the amount of fat in processed meat products to very low levels. The research to date and the commercial products available have limitations that are mainly categorized as maintaining and improving palatability including juiciness, flavour and mouth texture. The solution will be a collection of different technologies and strategies that must fit together, not unlike a jigsaw puzzle. The solution includes complete understanding of the process, ingredients and products by the consumer. The means of achieving these goals will centre on fat reduction, fat replacement and fat substitution.*

### *Introduction*

The last 10 years have brought about dramatic change in the type of processed meat products being offered to the consumer. The impetus driving many American meat researchers and most meat processors is the concern with fat levels in the diets. Animal products provide over 1/2 the fat and nearly 3/4 the saturated fat in the U.S. diet (N.R.C., 1988). This has stimulated the introduction of distinctly new products, and also the modification of existing formulations. Rust (1988) made the observation that the salt content of processed meats has likely dropped 20% in the last decade. Reduced fat luncheon meats and hams are increasingly available in the market (Pehanich, 1985). It is very common to observe restructured ham products that are 95% and 97% fat free. Frankfurters and bologna products are being offered that contain 10% or less fat.

The United States is characterized as having a market-driven economy. Several factors in the market have pushed the transformation of processed meat product formulations which had remained largely unchanged for years. Among the most influential of these factors is the concern over diet, including its relationship to the occurrence and progression of chronic disease such as heart disease and cancer.

A report issued by the U.S. Surgeon General (USDHHS, 1988) summarized and reinforced this linkage, which has been publicized widely in materials of numerous health organizations. The leading cause of death in the United States is coronary heart disease, followed by cancers (accounting for 35.7% and 22.4% of all deaths, respectively). Improper diets have been implicated as causative or contributory agents in these two causes of death, along with three others listed in the top ten causes of mortality. The factors considered to be most improper in these diets are an excess of fat and cholesterol.

The evidence for the association between fat intake and chronic disease are found in clinical, epidemiological and animal studies. A common thread that runs through all of these studies is the difficulty in separating completely diet from genetic, environmental or behavioral causes (USDHHS, 1988). These type of studies need to be analyzed very critically.

The existence of evidence supporting the link between excessive fat intake and chronic health problems has prompted the publication of dietary recommendations concerning the intake of fat and other nutrients. Recommendations from the National Academy of Sciences and the Surgeon General were reported by Peterkin (1991). It is now recommended that fat not account for more than 30% of one's total caloric intake and that saturated fat account for no more than 10% of total caloric intake.

Processed meats require a drastic fat reduction in order to fit within this guideline on an individual food basis. A 94% fat-free meat may still derive 51% of its calories from fat. A fat level of 30% contributes 84% of the total calories of the product (Shand and Schmidt, 1990). It is not reasonable to expect all meat products to fall within this recommendation; efforts must be taken to produce products that target these goals. In a recent survey, 74% of those consumers polled indicated that they were reducing fat in their diets (Hammock, 1991). However, this same author cited another survey which revealed that only 13% of those polled rated *how good the food is for you* as the most important factor in deciding whether to purchase a product. Palatability still remains a stronger variable in the purchase decision. Hammock (1991) stated that consumers will act on the healthy diet idea only when it doesn't mean sacrificing taste or convenience, and that the under-estimation of taste promises failure for low-fat products.

Low-fat processed meat products are successfully being marketed. Success has been very evident in the production of ham products of less than 10% fat, and most recently in the production of ground beef patties with less than 10% fat. In the area of finely comminuted products, fat plays a large role in the characteristic texture and overall palatability of these products. A simple fat reduction in these products results in an increase in product hardness (Sofos and Allen, 1977; Decker *et al.*, 1986; Hand *et al.*, 1987; Claus *et al.*, 1989) and increased formulation cost.

The USDA answered an industry request for more flexibility in producing these products (USDA, 1988) by changing the amount of added water allowed in the formulations. Presently, the amount of added water and fat in combination cannot exceed 40%; the maximum of 30% fat is still a USDA requirement. This allows the substitution of added water for fat, which will offset some of the rubbery texture often found in lower fat products. The addition of water will also reduce formulation cost only if that water can be successfully bound and not lost during thermal processing (Claus *et al.*, 1989).

Numerous non-meat ingredients are available today as texture-modifying and water binding agents. While not always marketed as such, they act as fat substitutes, softening the texture and binding water to retain juiciness. Shand and Schmidt (1990) reviewed some of the various protein and polysaccharide agents used in low fat products. The level of success of these agents is somewhat product dependent. These compounds must be listed on any statement of ingredients. Consumers are more willing to accept the presence of these non-meat ingredients, especially if they meet their tastes and needs (Neuwirth, 1991).

Wirth (1991) stated that the texture of low-fat products could be improved with the addition of high collagen meats. Jones (1984) stated that high collagen meats might act to dilute the stronger binding myofibrillar proteins and soften the texture of low-fat products. Processors have limited the usage of these high collagen meats in standard fat level formulations, due to decreased emulsion stability. Kramlich (1971) recommended that sausage formulation should not contain more than 25% high collagen meat. Recommendations such as this have generally been made for products of standard fat levels, with collagen in the unmodified form. Published research on the effects of chemically or physically modified connective tissue on finely comminuted products at lower fat levels is limited.

Beef connective tissue is a high collagen meat source and more available as a raw material today. It is being produced as a by-product of mechanical desinewing. Lean ground beef trimmings from desinewing have improved functionality and quality for such products as cooked salami (Gillett *et al.*, 1976) ground beef patties (Cross *et al.*, 1978) and frankfurters (Berry *et al.*, 1981). A connective tissue fraction is also yielded, which is currently being rendered at a low recovery value. The red meat industry is interested in adding value to this by-product.

The objectives of this review paper are to summarize the current state of the science and the industrial applications of the concepts of processing meat to meet the consumer demand and needs. While low-fat applications are but one of the forces driving changes in the processed meats field, this is a major factor for the current and near future changes. With this as the driving force, the challenge for science and processors is significant and the opportunities are great.

### *Enhancing low-fat comminuted meat products*

Claus *et al.* (1989) conducted an extensive work that characterized low fat/high added-water bologna. As added water was increased, post mincing temperatures and batter viscosity declined. High added water (>25%) formulations exhibited the highest cookout in emulsion stability tests and the highest smokehouse losses. In general, as fat decreased and added water increased, smokehouse losses increased. Additionally, purge losses during vacuum storage were more substantial with an increase in added water.

Changing formulations produced the darkest (visual appraisal) with the 5% fat/25% added water product. The highest Hunterlab 'L' values and lowest 'a' (redness) values were found in the control (30% fat/10% added water) bologna (Claus *et al.*, 1989).

Sensory juiciness scores were improved with greater amounts of added water (Claus *et al.*, 1989). Cohesiveness and firmness (as measured by the trained sensory panel) both decreased with an increase in added water. They speculated that the greater amounts of water made less hydrophobic sites available for protein-protein binding. Within levels of added water, decreases in fat were accompanied by greater sensory elasticity and firmness. Objective textural measures were highly correlated with the sensory scores in this data. Low fat bologna was harder, more elastic and required more energy to compress than higher fat formulations; the addition of higher levels of water overcame some of these characteristics (Claus *et al.*, 1989). Claus *et al.* (1990) noted that the ionic strength of low fat/high added water formulations would be lessened due to the greater amount of water. These authors massaged the batters in an attempt to extract more protein. None of the measures attempted in this study could increase the firmness of low-fat/high added-water bologna to the levels of the controls.

### *Soy protein products*

Soy protein flours are used as they are high in protein, possess some water and fat binding ability and are a low-cost ingredient (Rakosky, 1970). Soy protein is marketed in a variety of forms, based on the concentration of protein in the product. Sofos and Allen (1977) used textured soy protein in wiener-type products. Sensory texture scores tended to decline, Instron hardness increased, and oven shrink increased as fat was replaced with hydrated textured soy protein. Matulis *et al.* (1989) found that soy protein increased sensory and Instron hardness values of low-salt frankfurters. In addition, these authors noted that moisture content declined and off flavor intensity increased with the addition of soy protein to any formulation in this study.

Decker *et al.* (1986) was more successful in elucidating a favourable response to the addition of soy protein to low fat products. The addition of hydrated isolated soy protein (ISP) to 15% fat formulations enhanced the juiciness of these products to a level near the 30% fat controls. In general, 15% fat formulations approached the 30% fat controls when more than 20% of the lean meat was replaced with hydrated ISP.

### *Polysaccharides*

Recently, this group of ingredients has received attention as fat substitutes and water binding agents. Wallingford and Labuza (1983) investigated the water binding of various gums in low-fat meat emulsions. They found xanthan gum to be a very good water binding agent, followed by carrageenan, with pectins providing the poorest water binding.

Foegeding and Ramsey (1986) investigated a variety of gums in low fat meat batters. Batters with 0.2% methylcellulose exhibited greater cooking losses than control batters or any low fat batters that contained the other gums in their study. The various carrageenans in this study appeared to increase water holding capacity (WHC) through a gum-water or gum-protein-water interaction. Foegeding and Ramsey (1987) found that iota carrageenan improved the water binding ability of gelled meat batters, whereas xanthan gum and kappa carrageenan had no effect on this trait. Xanthan gum was successful in decreasing the textural properties of these batters. The authors concluded that these gums selectively affect certain traits and that a combination of these ingredients may be the best strategy to improve overall palatability and processing traits.

Lin *et al.* (1988) studied the effects of carboxymethyl cellulose (CMC) of different molecular weights on low-fat frankfurters. High molecular weight CMC frankfurters were equal to control frankfurters for emulsion stability, while the molecular weight of CMC had no effect on smokehouse yields. A textural profile analysis revealed that all parameters except cohesiveness decreased with the addition of CMC. These authors hypothesized that CMC acted to disturb the protein-water or protein-protein gel network.

### *Alteration of fat component*

Researchers have attempted to manipulate the fatty acid makeup of processed meats while at the same time reducing the fat content. Marquez *et al.* (1989)

substituted peanut oil for beef fat in reduced fat beef frankfurters. The reduced fat products were firmer, darker, had lower cooking yields, were less juicy and less desirable than frankfurters in the 20-30% fat range. The substitution of peanut oil for fat had little effect on any of these variables. The authors concluded that any minor differences in palatability could be masked by condiments in a product such as the frankfurter. The fact that the type of fat had little effect in low fat formulations would indicate that the presence and not the characteristic of the fat component is more important in low fat products.

This may not be true for all oils. Park *et al.* (1989) included fish oil as the major fat source in low-fat frankfurters and found the flavour to be very objectionable. The presence of monounsaturated fats had no effect on the stability of these frankfurters. Low-fat frankfurters with added high oleic acid sunflower oil (HOSO) possessed lower processing yields and were rated as firmer and more springy than the higher fat counterparts. The addition of monounsaturated oils to low fat products may change the fatty acid makeup to one that is perceived to be more desirable; however, the addition of oil has little effect on the poor texture and low processing yields of low fat products. Park *et al.* (1990) followed this study with one that combined HOSO and high levels of added water. This combination of ingredients was found to be similar in texture and processing yields to those of higher fat controls. The fact that high added-water frankfurters did not experience decreased yields in this study might indicate a link between fat softness and water binding ability.

### *Other formulation measures*

Stillwell *et al.* (1970) examined the effects of altering swine diets on processed pork products. Pork sausage made from pigs fed a control diet was preferred over sausage from pigs fed a diet with 20% safflower oil. No differences in consumer acceptability or willingness to buy were noted between frankfurters from control diet pigs and pigs fed a diet with 20% safflower oil. St. John *et al.* (1986) attempted to alter the fatty acid makeup by including in frankfurter formulations trimmings from pigs fed diets high in canola oil. The authors successfully increased the unsaturated fat levels in these formulations, with few palatability and textural differences being noted. Similarly, only slight differences were noted in this study when the total fat content decreased from 28% to 22%. This finding supports the argument that fat reductions in this magnitude can be made in many products without a significant alteration in product palatability.

Gregg *et al.* (1993) evaluated the effect of massaging high-water low-fat bologna formulations. Massaging for 2.5 hours increased cohesiveness, and the low-fat high-water treatments were more juicy than the high fat formulations. Cooking and purge losses were less in the high fat treatments.

Work reported by Hull *et al.* (1992) evaluated white bean and rice carbohydrates as a replacement for fat in beef frankfurters. While acceptable products were produced, smokehouse yields and purge losses were lower for the high fat formulations. High-added water treatments were found to be softer. Flavour problems with these two carbohydrates were resolved by using additional spice.

Lee *et al.* (1987) examined processing parameters on frankfurter texture. A decrease in chopping time resulted in frankfurters that were less firm, chewy and elastic. Hand *et al.* (1987) altered salt levels in an attempt to modify the texture of low-fat frankfurters. These authors found that low-salt, low-fat frankfurters were the best alternative to their high-fat/high-salt counterparts. Pre-blending had little effect on the textural or palatability properties of these products. The use of spray dried beef broth (Blackmer, 1992) illustrated another application of a high-flavour-profile recovered protein. This product, recovered during rendering helps to bind water and increases the flavour profile but can be a significant source of added salt and formulations should be adjusted accordingly. Low-fat ground beef formulated to 9% fat containing the spray dried beef broth had texture and palatability similar to or more desirable than beef patties with 16% fat. In another study, Blackmer (1992) compared iota carrageenan and isolated soy protein. In this study the iota carrageenan was more desirable than the isolated soy protein patties and very similar to 20% fat control patties. These ingredients all have considerable use in processed meats based on their functionality and palatability.

An often overlooked approach, perhaps due to its simplicity, is to lower the fat in the raw materials. This can produce a lower fat product, without the need for non-meat ingredients. This approach offers opportunities where a significant reduction in fat, yet not formulating for very low fat levels, is desired (such as in pork sausage). Schultz (1991) demonstrated in foodservice pork sausage that the reduction of fat to as low as 16% produced very acceptable palatability scores that were essentially the same as those produced in the higher fat controls. While this approach changes the cost of production, for the market that does not prefer non-meat ingredients, there are significant improvements that can be made in just lowering the amount of fat, as long as palatability scores are monitored and maintained.

### *Utilization of high collagen raw materials in processed meats*

Collagen has been long considered a protein of low functionality and its use limited in processed meats. Gillett (1987) observed rendered fat, grainy texture, lower consumer cook yields and higher post-mincing temperatures when sinew was added to beef frankfurters. Additionally, penetrometer scores were higher after consumer cooking for the high collagen formulations. The sinew in this research was obtained from beef chucks, shanks and navels. The high collagen treatments consisted of almost 42% of the formulation weight as unmodified sinew and fat levels of 19-22%. Collagen made up 23-33% of the protein content in these formulations. Clearly, these levels of collagen are not feasible in a finely comminuted meat product, as it is difficult to obtain a fine, ordered protein matrix.

There is a growing body of literature indicating that lower levels of collagen, modified by physical or chemical means, can be a functional ingredient in finely comminuted meat products. Jobling (1984) listed several benefits of collagenous proteins in meat products. This author noted that bone collagen has a high absorption capacity for fat and water, and that the condensation of collagen might contribute to the succulence and flavor of a meat product.

Enzyme hydrolyzed pork and beef skin collagen has been used as a substitute for non-fat dry milk in sausage emulsions (Satterlee *et al.*, 1973). Greater emulsion stability, softer product texture, and higher fat and water contents were noted when the hydrolyzed skin was added to these products. The authors commented that enzyme hydrolysis completely degraded the protein, so that the hydrolyzate is merely a mixture of peptides. The effects due to the thermal shrinkage of collagen would not be expected in these products.

Rao and Henrickson (1983) added 20% food grade hide collagen to bologna formulations of different fat levels. This level of collagen did not alter the emulsion stability, water activity or expressible juice in these formulations. Higher shear values (Kramer and Warner-Bratzler) were observed with higher collagen values; they attributed this to collagen protein filling in the myosin protein matrix. This collagen source contained a small amount of soluble collagen, which may explain the fact that pockets of gelatinized collagen in the product were not present. Bologna was less red in colour when the hide collagen was added. Higher levels of residual nitrite were found in the collagen treatment, due to the lower amount of myoglobin present to bind nitrite.

Sadowska *et al.* (1980) examined the effects of high collagen levels on meat homogenate rheology. Pre-cooked pig skin collagen increased the viscosity of these batters; they attributed this to the interaction of denatured collagen with water. As the amount of raw pig skin collagen (as a percentage of total protein) increased to 20%, the viscosity of meat batters decreased. Homogenates were also manufactured with varying levels of high connective tissue meats. As the levels of these meats increased, batter viscosity, final product elasticity, yield limit and amount of drip decreased. These authors concluded that the effects of collagen can be altered by pre-treatment of the collagen source as well as by modifications in time and temperature of cooking.

The pre-treatment of pork skins is a method employed by European and Canadian sausage makers (Wachter, 1991). Pig skins are chopped with ice and a low-pH polyphosphate, and preblended for a 24 hour period. The pre-blending procedure has been noted to 'soften' the skins, making them more desirable for incorporation into sausage formulations. Quint *et al.* (1987) pre-emulsified pork skin to include in the production of low fat pork loaves. Skin pre-emulsion was added in place of lean meat at a level of 7.5%. In the low-fat products, this level of pre-emulsion increased the redness, yellowness, hardness, adhesion and Kramer shear values. No pre-emulsion effect was seen on consumer ratings of texture or overall desirability, even when compared to a high fat control. It is assumed that this product was evaluated in the cold state; these effects could be much different if the product were analyzed warm, allowing any gelatinized collagen to melt. As noted by Rao and Henrickson (1983), the collagen seemed to become integrated into the myofibrillar protein matrix, causing the higher objective shear values.

Tripe was added to bologna formulations, and a decrease in product hardness and chewiness was noted (Jones and Mandigo, 1982). Increasing levels of tripe decreased the viscoelastic properties of the raw meat batters. No differences between the 0, 10 and 20% treatments were observed for total fluid loss; 30 and 40% tripe emulsions were less stable. This corresponds to the fact that gelatin pockets were present only in the 30 and 40% tripe formulations. Less than a 1% difference existed in smokehouse yields between all of the treatments, with the highest yields being noted in the 10-30% tripe formulations. The yield data corresponds with other research (Gillett, 1987) that has not observed a dramatic decrease in product yields with an increase in collagen.

The amount of collagen that could be solubilized using the Hill (1966) procedure changed very little from 0 to 40% tripe, emphasizing the low levels of soluble collagen found in tripe. The percentage of soluble collagen decreased markedly as the total collagen level increased. Most collagen related research has addressed total collagen levels; research is needed to address the impact of varying levels of soluble and insoluble collagen. A consumer sensory panel conducted on these products found that for all palatability traits, the control was preferred over the tripe treatments. Lower levels of tripe (10 and 20%) were rated as slightly acceptable, significantly lower ratings being noted with the 30 and 40% levels. Jones (1982 and 1984) questioned if other sources of collagen would provide similar results.

The utilization of beef connective tissue in low-fat, finely comminuted meat products has been explored. Quint (1987) added 0, 10, 20 and 30% frozen, flaked beef connective tissue to 15 and 30% fat frankfurters. Batters were less stable with larger amounts of connective tissue, yet these effects were not as great in the lower fat levels. Thermal processing yields increased with an increase in connective tissue and an increase in fat. Modified beef connective tissue had no effect on objective textural measures or the sensory properties of low-fat frankfurters.

Eilert *et al.* (1991a) added 0, 10, 20, 30 and 40% frozen, Comitrol flaked beef shank connective tissue to frankfurters of 8, 16 and 24% fat. The temperature rise during emulsification increased when the connective tissue level increased from 10 to 40%. Raw batters with higher levels of connective tissue required more force for extrusion, further indicating their more viscous nature. Fat and connective tissue interacted to affect emulsion stability total and fat losses. Losses peaked at 24% fat, 20% connective tissue, while virtually no differences existed within fat levels at 0 and 40% connective tissue. Processing losses tended to decrease with an increase in connective tissue. Kramer shear values were higher in formulations with increased levels of beef connective tissue (Eilert *et al.*, 1991b). Higher levels of connective tissue reduced the hardness and chewiness of 8% fat frankfurters. Consumer sensory analysis found that modified beef connective tissue had no effect on product juiciness or flavour. Texture and overall desirability followed almost identical interactions. Frankfurters with 20% connective tissue received the highest ratings within the 8% fat level; 10% connective tissue was rated as most desirable in the 16%and 24% fat frankfurters. Blackmer (1992) demonstrated the effectiveness of modified connective tissue in low-fat ground beef patties. Connective tissue utilized after the second pass through the Baader Desinewing machine, then modified by freezing/shattering had greater water retention and decreased shear force when compared to first-pass connective tissue in low-fat ground beef patties. Because of higher collagen contents, colour of products made with the second pass connective tissue were lighter. Sensory tenderness, Kramer shear and expressible moisture improvements from the modified connective tissue make it an attractive texture modifier in processed meats.

It has not been determined how such physical modification of connective tissue will alter its effect on a meat product. Particle size reduction prior to batter formation will insure uniform distribution in the product. Adding the connective tissue in the frozen state may act as ice to minimize the temperature rise during emulsification. The addition of modified beef connective tissue has not resulted in a consistent alteration in product texture. This connective tissue has been shown to improve the processing yields of finely comminuted meat items; further research is necessary to address modified connective tissue as a water binding agent.

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