LOW-FAT MEAT PRODUCTS -TECHNOLOGICAL PROBLEMS WITH PROCESSING

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SUMMARY

Diet and health advice serve as a driving force to redirect the types of foods considered to be most beneficial in terms of improved health and quality of life for Americans. Although meat cuts have become leaner, products such as ground beef, fresh pork sausage, coarse ground sausages and emulsified sausages traditionally have higher levels of fat. However, these products offer the greatest opportunity for fat reduction by reformulation with fat substitutes. Fat replacements should contribute a minimum of calories to a product and should not be detrimental to organoleptic qualities. Most substitutes can be categorized as: leaner meats, added water, protein-based substitutes, carbohydrate-based substitutes and synthetic compounds. Reducing the fat content to ~ 10% fat often results in cooked ground beef that is bland and dry with a hard, rubbery or mealy texture. Reformulation with fat substitutes can cause a reduction in particle binding, darker product color, lack of beef flavor, reduced browning reactions and shorter microbiological shelf-life. Other problems that occur with low-fat (5-10%) fresh or cooked/ smoked sausages are reduced cook yields, soft mushy interiors, rubbery skin formation, excessive purge in vacuum packages, shorter shelf-life and changes in sensory qualities after cooking or reheating. However, some combinations of fat replacements that mimic the mouthfeel and textural characteristics of fat offer potential for development of low-fat meat products.

RATIONALE FOR LOW-FAT MEAT PRODUCTION IN THE USA

Diet/Health Concerns and Government Recommendations to Reduce Fat Consumption

According to the Surgeon General's Report on Nutrition and Health (McGinnis and Nestle, 1989), coronary heart disease (CHD) continues to be the number one cause of death among adults in the USA. A decade earlier, the Report urged Americans to improve their health and reduce the risk of CHD by: 1) reducing dietary intake of saturated fat, cholesterol, salt, and sugar; 2) increasing their consumption of complex carbohydrates; and 3) taking in only enough energy to maintain desirable weight, or to reduce if overweight. A subsequent report in 1988 concluded that over consumption of foods high in fat are often at the expense of foods high in complex carbohydrates and fiber. The American Heart Association, National Cholesterol Education Program and other professional health organizations have recommended: lowering the daily intake of dietary fat to an average of 30% of total calories, consuming less than 300 mg of cholesterol per day, and limiting saturated fat to < 10% of total calories as a means of reducing the risk of developing coronary heart disease. Consumers are advised to choose lean cuts of red meat, use low-fat cooking methods, eat moderate amounts of meat (approximately 170 g/day, cooked), remove visible fat, and substitute fish or skinless poultry for choices high in saturated fatty acids. Thus, diet and health advice serve as a driving force to re-direct the types of foods considered to be most beneficial in terms of improved health and quality of life.

Meat Consumption Trends

From 1970 to 1991, total beef consumption has declined 19.9% but consumption of hamburger or ground beef has increased by 23.2% from 10.0 to 13.0 kg (21.9 to 28.5 lbs)/capita. According to the USDA Handbook 8-13 (1986), regular raw ground beef contains 26.6 g fat/100 g edible portion but Savell et al (1991) reports that on the average ground beef at the retail level has a fat content of 20%. Further reduction in the fat content of ground beef could provide positive health benefits to Americans. Statistics show that 47% of all beef produced is consumed at fast-food outlets, restaurants, hotels, cafeterias, supermarkets or similar businesses and approximately 60% of all beef used in food service applications is ground beef. Because excess fat remains a problem in ground beef, opportunities exist to significantly reduce fat consumption by reformulation or substitution of the fat in this popular meat product.

Meat Industry Move Toward Leanness

The National Consumer Retail Beef Study and the National Beef Market Survey (Savell et al, 1989, 1991) indicated that consumers would purchase more beef if the fat were closely trimmed. As a result, retail supermarkets began trimming external fat from retail cuts. By the late 1980's, the average external fat content was 0.32 cm (1/8 inch) with over 42% of the retail cuts having no external fat. These studies indicated a significant change in consumer attitude toward fat and documented the availability of leaner whole-muscle retail cuts to consumers.

Pork carcasses have also become leaner since 1955 declining from 9.3 kg fat /100 kg carcass to 5.3 kg fat /100 kg carcass (USDA, 1983). However, according to USDA Handbook 8-7 (1980), fresh pork sausage on the average contains 40 and 31% fat on a fresh and cooked weight basis, respectively. Bologna and frankfurters on the other hand average 28% fat while similar poultry products contain ~ 15% fat. Thus, additional opportunities exist for production of leaner sausages and other processed meats to meet consumer expectations.

Consumer Attitudes Toward Use of Fat Substitutes

Individual attitudes toward fat substitutes vary, but generally, food products with fat substitutes are acceptable if they taste good, are reasonably priced, have nutritional merit and elicit a widespread perception of healthiness, although labeling and safety issues may still be

of concern. Cost of low-fat products may be 10 to 30% more per kg or lb than their higher fat counterparts, but the high degr consumer interest in reduced-fat foods suggests that products are not currently available in the marketplace to meet consumer demand

METHODS OF FAT REDUCTION

Trimming External and Intermuscular Fat

As reported previously by Savell et al (1991), supermarket retailers have trimmed all the external fat from 42% of the beef retail cu result of consumer demand. In addition, they found that overall subcutaneous fat thickness for steaks and roasts from the chuck, rib and round was only 0.32 cm (~ 1/8 inch) and that ground beef was leaner. When these data were compared with the 1986 U Handbook 8-13, beef steaks and roasts had 27.4% less fat and ground beef contained 10.2% less fat.

Genetic and Dietary Modifications

Compositional variation exists among and within breeds of livestock due to genetic selection for specific traits (CAST, 1991). In addi physiological and chronological age at slaughter, level of nutrition and management systems are contributing factors that determin composition of carcass cuts and trimmings. Modifications of ruminant diets with forage and grain can cause large differences in fa content of edible tissues and slight alterations of the fatty acid profile. Inclusion of different types of fat in monogastric (pork, po turkey) diets can dramatically alter carcass composition and affect processing characteristics (CAST, 1991). For example, St. John (1987) found that feeding pigs diets containing 20% canola oil (60-65% oleic acid) decreased the level of saturated fatty acids in adi and muscle tissue by 25 and 19%, respectively. However, at that level of fat substitution, the primal cuts were oilier and less firm w could interfere with processing efficiency and fresh product appearance. In similar studies, Rhee et al (1990) reported that fresh cut pigs fed 10 to 12% canola oil were not different in terms of cooking losses or sensory properties, but Shackelford et al (1990 a,b similar diets to pigs and noted lower favor and palatability scores for cured boneless hams, bacon, low-fat fresh sausage and ferm sausage.

Fat Replacements or Substitutes

Processed meats such as ground beef, coarse ground sausages and emulsified sausage products are typically higher in fat than wh muscle fresh or cured products, with bacon being an exception. Most cooked and cooked-and-smoked sausages may contain up to 30% but an industry average according to Drs. Joseph Sebranek and Glenn Schmidt is approximately 20%. As much as 50% fat is allowed fresh pork sausage but the industry average is ~ 36%. Although processed meats are typically fatter than fresh retail cuts, they hav greatest opportunity for fat reduction and/or modification because their nutrient composition can potentially be altered by reformulat with a fat replacement or a combination of fat replacements.

Fat replacements or substitutes are ingredients that contribute a minimum of calories to formulated meats and do not dramatically flavor, juiciness, mouthfeel, viscosity or other organoleptic and processing properties. Most substitutes are used for partial replacement the fat and can be categorized as: 1) Leaner Meats (fat reduced beef, partially defatted chopped beef/pork, mechanically separated deboned beef/pork /poultry/turkey); 2) Added Water; 3) Protein-Based Substitutes (blood plasma, egg proteins, milk caseinates, non dry milk, oat bran, soy protein flours/concentrates/isolates, surimi, vital wheat gluten, wheat proteins, whey proteins); 4) Carbohyd Based Substitutes (fibers, cellulose, starches, maltodextrins, dextrins, hydrocolloids or gums); 5) Synthetic Compounds (Polydextro Olestra® or sucrose polyester).

TECHNOLOGICAL PROBLEMS ASSOCIATED WITH PROCESSING - BY PRODUCT CATEGORY

Fat is a calorie dense nutrient that provides flavor, texture, juiciness and water entrapment in ground beef and fresh pork sausage. excessive fat reduction, these products become bland and dry and the texture can be hard, rubbery or mealy. Some US companies already experiencing difficulties marketing low-fat beef products. Reformulation using fat substitutes has caused a reduction in pro binding, darker product color and shortened refrigerated shelf-life because of gassy, swollen packages. Other problems that occur low-fat, cooked-and-smoked sausages are reduced cook yields, soft and mushy interiors, rubbery skin formation, excessive "wee purge in vacuum packages, shortened shelf-life and changes in mouthfeel of the product after conventional or microwave reh Although some understanding of the use of fat replacements has been gained, much remains to be learned about the interaction substitutes with classical sausage ingredients, processing procedures, storage conditions and final product preparation.

One issue that often causes concern among consumers is finding an unfamiliar ingredient on the label even though the ingredient i approved and widely used in other food product applications. Processors are therefore sometimes hesitant to incorporate an ingredi fat reduction purposes which might cause concern or confusion on the part of the consumer.

A. Ground Beef and Hamburger

The Nutrition Labeling and Education Act of 1990 has been responsible for food labeling reform by the Food and Drug Administ (FDA) and modified the proposed standards for labeling leaner meats. Ground beef products with no more than 10% fat will be labeled "Lean" and products with less than 5% fat will be labeled "Extra Lean." The United States Department of Agriculture-Food

nd Inspection Service (USDA-FSIS) regulations now allow low-fat ground beef products to contain no more than 30% of a combination of fat and added substances with a maximum of 10% total fat.

1. Lean Raw Material

One method of producing low-fat ground beef is to use leaner raw materials to achieve a 10% fat limit. Several studies have provided information on the chemical, physical and sensory characteristics of regular ground beef (25 to 30% fat). However, only recently have studies begun to characterize low-fat ($\leq$ 10% fat) properties.

Research conducted by Cross et al (1980), Berry and Leddy (1984), Kregel et al (1986), Hoelscher et al (1987) and Troutt et al (1992a) reported the effects of reducing the fat content of beef patties. In general, as the fat content is reduced from 25 to 30% downward to 5 or 10%, cooking loss, drip loss, juiciness, beef flavor, tenderness, oily mouth coating, and consumer acceptance decreases. Also, as fat content declines, intensity of red color, cooking times, beef patty hardness, cohesiveness, springiness, crumbliness, density, Warner-Bratzler and Allo-Kramer shear force values and Instron texture profile parameters increase. Increasing cooking endpoint temperatures (from 71° to 77°C) tends to accentuate the less desirable traits noted between high and low-fat patties.

Cholesterol content of raw beef patties has been shown to increase as fat content increases from 5 to 30% fat (Kregel et al, 1986; Hoelscher et al, 1987). However, after cooking, the cholesterol content of patties, ranging from 70-75 mg/100g, is not different on an "as eaten" basis. Huffman and Egbert (1990) found that beef patties with approximately 20% fat were highest in overall acceptability over a fat content range of 5 to 25%. They also noted that overall palatability of low-fat ground beef was improved slightly by a final grind through a 0.48 cm (3/16 inch) plate rather than a more common 0.32 cm (1/8 inch) plate.

Griese (1992) reported that Fat Reduced Beef (FRB), a defatted and desinewed frozen beef flake, has potential as an ingredient for low-fat ground beef products. FRB contains approximately 10% fat, has a protein efficiency ratio (PER) of $\geq$ 2.5 and is manufactured from beef trimmings with $\geq$ 12% lean on the surface.

2. Protein-Based Fat Replacements

Plant and animal derived proteins have been used as binders and extenders in ground beef to improve yields (water and fat binding), reduce formulation costs, maintain nutritional value, enhance functional properties (water holding capacity) and decrease fat and cholesterol content. Protein ingredients do not appear to tie up water-soluble flavor components as much as carbohydrates, and their hydrolyzates are often added to meats to achieve a brothy or meaty flavor note.

The most frequently used protein-based fat replacements in the US are: textured and granular forms of soy protein flours, concentrates and isolates; non-fat dry milk, caseinates and whey proteins; wheat flour and vital wheat gluten. Singly or collectively, most flours (50% protein) and concentrates (70% protein) are used at levels up to 3.5% (dry weight basis) and hydrated 3 parts water:1 part protein while isolates (90% protein) are limited to 2% (dry weight basis) of the total product formula and hydrated on a 4:1 basis.

Soy proteins have traditionally been the ingredient used most for extending ground beef or reducing fat content. Generally, as higher levels of soy protein flours and concentrates are incorporated into beef patties, total cooking loss, moisture loss, caloric density, cholesterol content, meat aroma and flavor intensity, incidence of rancid off-flavor and shear force decrease while rate of raw patty discoloration, tenderness, soy flavor and in some cases, juiciness increase (Berry et al, 1985; Brown and Zayas, 1990; Drake et al, 1975; Liu et al, 1991; Zipin et al, 1981). Decreasing the fat content in beef patties or displacement of fat with soy protein can cause increased tenderness but a decline in beef flavor and cohesiveness (Drake et al, 1975). Kotula et al (1976) reported soy proteins (textured and concentrate) to inhibit oxidative rancidity development in patties having 20% fat and stored over a 12 month period at - 17°C.

Berry et al (1985) compared ground beef patties (22% fat) containing 20% rehydrated soy flour, concentrate or isolate with and without iron and zinc fortification. Soy flour patties had the highest cook yields, were more tender and had more soy flavor than those with isolate, but the isolate imparted textural characteristics more similar to all-beef patties than either the flour or concentrate. When fortified with iron or zinc, soy patties had more rancid flavor possibly due to catalytic activity of the metals accelerating lipid oxidation.

The type of soy protein used can cause proliferation of microbial growth leading to spoilage and reduced color shelf-life. Keeton and Melton (1978), Harrison et al (1981) and Draughon et al (1982) reported psychrotropic and coliform bacteria numbers to increase with increasing levels of textured soy protein in ground beef, but Liu et al (1991) found no differences in patties when frozen textured soy isolate was used. These differences were likely due to the availability of simple sugars in the soy component, processing temperature, temperature of storage and method of packaging.

As with most low-fat products, ground beef with soy proteins as a partial fat replacement will require additional seasonings or flavorants to enhance palatability. Ingredients such as sodium tripolyphosphate, encapsulated salt, hydrolyzed vegetable protein, beef extract, hydrolyzed yeast extract, hydrolyzed milk proteins and meat-based flavors can be included in ground beef formulations to provide acceptable meat-like flavor comparable to a 20% fat patty.

3. Carbohydrate-Based Fat Replacements

Carbohydrates such as starches, gums (hydrocolloids), maltodextrins and dextrins are currently included in ground beef to improve cooking yields, increase moisture retention, reduce formulation costs, modify product texture and improve freeze-thaw stability. Use of these ingredients has increased with the development of low-fat products (Shand et al, 1990; Keeton, 1991).

Carrageenan . Huffman and Egbert (1990) and Egbert et al (1991) compared all-beef patties containing ~ 20% fat to those with 8% fat with or without 0.5% iota carrageenan, 10% water, 0.4% encapsulated salt and 0.2% hydrolyzed vegetable protein. Griddle-broiled carrageenan patties with 8% fat were rated more tender by a sensory panel and contained 15.8% more moisture, 58% less fat, 16% (7 mg/100g) less cholesterol and 37% (100 kcal/100g) fewer calories than the 20% control. Eight percent fat all-beef patties were less juicy, had less favor intensity, higher cooking yield and greater shear force values than either the 20% control or 8% fat carrageenan patties. Patties with 20% fat had the highest cooking losses but lowest shear force. Serving temperature also appears to be more critical for low-fat patties than regular fat patties.

McDonald's Corporation adapted the low-fat carrageenan formulation developed by Huffman and Egbert (1990) and introduced McDonald's McLean Deluxe™ hamburger nationally in 1991. Other products using carrageenan include Healthy Choice™ (ConAgra Corporation), an extra lean (4% fat) ground beef product marketed as a 0.45 or 0.9 kg (1 or 2 lb) chub with an eight day refrigerated shelf life. Application of the carrageenan technology must be carefully controlled, otherwise, detrimental product changes will negatively influence consumer attitudes toward all low-fat ground beef products. Some concerns when using carrageenan-based products are: it is a non-traditional ingredient in a traditional product and its appearance on the product label; the low melting point (49°C) of carrageenan may cause premature loss of moisture or water-soluble flavors; fewer browning reaction products may develop during grilling or broiling thus reducing meaty flavors; and lack of meat flavor in ground beef after cooking and holding in fast-food service situations may decrease repeat customers.

Oat Bran and Oat Fiber. Oat bran or oat fiber appears suited as a fat replacement in ground beef and pork sausage products due to their ability to retain water and emulate the particle definition in ground meat in terms of both color and texture. Webb Technical Group developed an oat bran mix with flavorings and seasonings (Lean Maker™) and replaced a portion of the meat base with 3.0% oat bran and 7% added water. On a cooked basis, 10% fat beef patties with oat bran contained 12.7 g of fat, 69.6 mg of cholesterol and 132.9 when expressed on a 100 g basis. This represents 38% less fat, 15% less cholesterol and 25% fewer calories than a 20% fat control. Cooking yields were 15% more than 20% fat ground beef which should compensate for the 15 to 30% additional cost of producing low-fat patty.

Overuse or misuse of oat bran or oat fiber products can result in poor binding of the raw product causing difficulties with patty formation (reduced particle binding), reduced raw color appearance and stability, crumbly or mealy texture after cooking, off-flavors not normally associated with beef and shorter microbiological shelf-life for refrigerated raw products. Bran or fiber products will most likely be used in frozen products destined for food service operations.

Carrageenan and oat bran have been specified for use in the USDA Agricultural Marketing Service's School Lunch Procurement Program to encourage the use of low-fat beef patties in public school systems. However, careful formulation and selection of flavor enhancers is required to retain the meat flavor and texture equal to that of 20% fat ground beef. Revised cooking procedures for the school program are also needed to avoid overcooking and loss of juices, creating palatability problems and rejection of low-fat beef.

Starches and Maltodextrins. Starches and maltodextrins are glucose polymers typically derived from corn, oats, potatoes, rice, tapioca and waxy maize. Upon hydration, two polymeric forms, amylose and amylopectin, create a three-dimensional gel network entrapping water. Most fat replacement starches are pregelatinized to enable cold water swelling. In meat products, they improve yields and freeze-thaw stability, reduce syneresis and resist high shear or heat conditions.

Maltodextrins are created by cleaving starch amylose and amylopectin chains and typically have a dextrose equivalent of ≤ 20. These ingredients are relatively low cost and form a fat-like gel when hydrated. Oatrim™ and Leanesse™ are examples of oat and maltodextrins with less than one calorie per gram. Fresh, low-fat, chub-packs of ground beef made with Leanesse™ yield a product with 4 g of fat, 55 mg of cholesterol, 240 mg of sodium and 130 kcal per 113.4 g (4 oz) deriving only 28% of total calories from fat.

Berry and Wergin (1990) incorporated 8% modified pregelatinized potato starch gel (3% starch, 5% water) in beef patties with 4% and 8% fat. Gel treated patties had lower sensory flavor and juiciness scores, higher tenderness ratings, improved cook yields (4-6%) and a cost advantage due to the price of the starch. In a slightly different study, Minerich et al (1991) formulated ground beef patties (10, 15 and 20% fat) with and without 0, 15 or 30% Minnesota wild rice. As wild rice level increased, proportional decreases in cholesterol, fat, protein and ash content were observed with increases in percent carbohydrate and moisture. Wild rice patties, regardless of fat level, had higher cooking yields, lower thiobarbituric acid reactive substance (TBARS) values (indicating possible antioxidant activity) and were preferred by consumer panelists over regular ground beef. Growth rates of microorganisms in both low- and high-fat mixtures at refrig-

perature were not different. Troutt et al (1992b) concluded that a three-way combination of Polydextrose®, potato starch and either ger beet, oat or pea fiber reduced firmness and cohesiveness of 5 and 10% fat beef patties when compared to a 20% fat control. The gredient combination lightened raw patty color and reduced cooking losses (by 20 to 40%), beef flavor intensity, juiciness and oily outh coating scores. Although these ingredients could serve as fat replacements, further research was recommended to optimize their use beef patties.

Constraints on the use of starches and maltodextrins in ground beef appear to be: lightened color of the raw product, reductions in beef flavor intensity and juiciness, and reduced firmness and cohesiveness.

B. Fresh Pork Sausage and Cooked Coarse Ground Sausages

Meimeier and Prusa (1987) found that as the fat level increased in pork patties from 4 to 23%, the patties became more tender and juicy ked had increased oily mouth coating. Pork flavor was less pronounced in the 4% fat patties but cooking losses and cholesterol content were not different among fat levels when cooked to 71°C. When heated to 77°C, cooking losses were greater than at 71°C. As observed with the beef patties, fat reduction alone will not likely produce a palatable low-fat pork sausage, but additional ingredients are needed to stance eating quality.

1. Added Water

Pork sausage patties containing 25% fat and 13% added water showed greater cooking losses than a 15 or 35% fat patty with 13% added ater (Ahmed et al, 1990). However, 15 and 25% fat patties with 3% added water had less cooking losses than their 35% counterparts. Generally, it appears that for low-fat patties, the addition of excess water alone may be detrimental to cook yield, juiciness, and tenderness ld cause increased springiness and cohesiveness. As with ground beef, added water must be bound to effect a desirable low-fat pork product.

2. Protein-Based Fat Replacements

Additions of soy proteins, milk proteins and wheat proteins to low-fat fresh pork sausage formulations are expected to yield similar results t was obtained with low-fat ground beef patties.

Meimeier and Prusa (1991) determined that pork patties (8, 19 or 32% fat) with 2.5 or 5% dry- and wet-milled corn germ had higher ooking yields, increased tenderness scores than patties without corn germ. The wet-milled corn germ increased yellowness of the patty rface. Unfortunately, no sensory tests were performed on the low-fat pork sausage to evaluate palatability.

3. Carbohydrate-Based Fat Replacements

Konjac flour is a hydrocolloid which forms a strong hydrophilic elastic gel which has some of the sensory properties of fat but with a dramatic reduction in caloric content. Application for use in meat products is pending final approval by the USDA-FSIS.

Osburn (1992) incorporated rehydrated konjac gel into 10% fat prerigor pork sausage at levels of 0, 10 or 20% (0.25 and 0.5% konjac on a dry weight basis) and made comparisons to sausage having 40% fat. Konjac patties were redder in color, similar to controls in overall ppearance and slightly detectable at the 20% level. In comparisons to the 40% fat control, patties with 10% konjac had ~ 3% greater cook ield, were rated only slightly higher for shear force, springiness, cohesiveness, chewiness, hardness, denseness and fracturability and slightly lower for juiciness. TBA values and microbial growth were not affected by konjac flour. With the inclusion of 10 or 20% konjac in pork patties, fat was reduced by 77 and 80%, respectively, compared to the 40% control. In a companion study, Osburn (1992) found that low-fat (8%) cured smoked, coarse-ground lamb sausages manufactured with 10 or 20% konjac flour were less cohesive, springier and harder than and 8% fat control but that overall sensory scores were within a range that would indicate acceptability by consumers.

Some konjac gels are translucent and should be colored to avoid pigment absorption from the muscle tissues resulting in a "blood splash" appearance. In addition, seasonings and ingredients can be included in the gel to avoid flavor voids. It was also noted that during pan frying surface browning did not occur without caramel coloring in the seasoning mix.

Skrede (1989), compared cooked Norwegian sausages with 4% levels of potato flour and starches from potatoes, wheat, corn or tapioca with sausages containing 21% fat. She found the sausages with potato flour to have the highest cook yields and sensory traits while sausages with tapioca had the lowest.

Webb Technical Group, Inc. reported that a 10% fat pork sausage with 3% oat bran, seasonings and flavorings (LeanMaker™) plus 7% water yielded 33% more cooked product than regular fresh pork sausage (35% fat). The 10% sausage contained 10.6 g of fat, 70.5 mg of cholesterol and 194 kcal per 100 g, which represents a reduction of 66-75% fat, 20% cholesterol, and 48% calories compared to the regular fat patty.

C. Emulsified Sausage - Frankfurters and Bologna

The USDA-FSIS now permits fat and added water in cooked sausages to substitute for one another provided that their total does not exceed 40% and that the fat content is no greater than 30% (USDA-FSIS, 1990). Under this assumption, the fat content of an emulsion-type sausage could be a maximum of 30% fat with 10% added water or as low as 5% fat (on a practical basis) with 35% added water. However,

reducing the fat (essentially increasing the lean content) of emulsion-type sausages and adding water to replace the fat causes products to become firmer, more rubbery, less juicy, darker in color, more costly and less acceptable in terms of skin formation, mouth processing yield and increased purge in the vacuum package (Hand et al, 1987; Claus et al, 1989). Careful selection of fat replacers however, can provide increased water holding capacity, enhanced textural properties and reduced costs for sausage manufacture.

1. Added Water

Water-binding, rather than fat-binding, and textural characteristics are essential to the manufacture of low-fat emulsion products. Park (1990) found processing yields, aroma, flavor, juiciness and overall desirability of frankfurters containing 14-16% added water and 16% fat (~ 75% as high-oleic sunflower oil) to be equal to or greater than control frankfurters with 29% fat. In bologna formulas ranging from 30% fat/10% added water to 5% fat/35% added water and having similar protein content, Claus et al (1989) observed low high-added water bologna to be generally softer, juicier, more cohesive, and darker in color with greater cooking and vacuum packa purge loss than a control. Regression analysis indicated that bologna with 10% fat would require 24.3% added water to approximate sensory firmness of the control. In a subsequent study, neither massaging raw materials nor preblending prevented excess cooking lo and purge accumulation of a 10% fat/30% added water bologna (Claus et al, 1990). Based on these studies, substitution of fat with w water up to the USDA maximum results in a less than acceptable product. Thus, water binding or retention and duplication of the tex characteristics of fat become major problems when formulating low-fat emulsion products simply by fat substitution with added water.

2. Protein-Based Fat Replacements

Sofos et al (1977) reported that acceptable wiener-type products could be produced with 45-50% lean, 15-20% fat, 5% hydrated (1:1) protein isolate (SPI) and 25-30% hydrated (1:2) textured soy protein (TSP), but shrink and moisture loss would likely be high. Ensor (1987) on the other hand noted no cook yield differences in an emulsified knockwurst (24% fat) containing whey protein concentrate 1.75, 2.0 and 3.5%, WPC), calcium reduced non-fat dry milk (3.5%, RNFDM), and soy protein isolate (2.0%). Consumer sensory sco favored RNFDM and WPC (1.75%) for flavor, texture, juiciness and overall acceptability while Instron compression was slightly hi and more chewy than the controls. Overall, RNFDM and WPC were observed to be desirable fat replacements.

Protein-based fat replacements appear to offer substantial advantages to low-fat products, but improvements in textural characteristics reduce cohesiveness, hardness, springiness and similar traits are required. Combinations of gums, starches or proteins may offer poss combinations which mimic the mouthfeel and textural characteristics of a regular fat product.

3. Carbohydrate-Based Fat Replacements

Gums or hydrocolloids are used to regulate viscosity, form gels, stabilize emulsions, suspend particulates, control crystallization, in syneresis and encapsulate particulates. Wallingford and Labuza (1983) found xanthan gum to be more effective than carrageenan, gu bean gum and low methoxy pectin in preventing water loss from low-fat meat emulsion models while Whiting (1984) noted that algin xanthan gums (0.1-0.3%) improved water binding in low-fat frankfurters but were detrimental to gel strength. Foegeding and Ro (1986), however, concluded that kappa and iota carrageenan at levels of <1% were the most beneficial for holding moisture and increa hardness in 11-12% fat frankfurters. Hedonic scores indicated that low-fat franks with iota/kappa carrageenan were as acceptable a 27% fat control frankfurter. Hydrocolloids appear to offer potential for meat emulsion products either alone or in combination proteins or starches but further evaluations are needed to identify the most desirable combinations of ingredients and their effe improving water-binding, texture characteristics, cook yield, excess purge and microbial shelf-life.

Starches and Maltodextrins. Odio (1989) reported that modified waxy maize starch (MWMS), tapioca dextrin (TADE) and rice (RIFL) have potential as fat substitutes when added to low-fat (9 or 15% fat) frankfurters at 2.5-5.0% levels. Franks containing MW TADE, and RIFL were found to have similar flavor and texture profiles except for a slight starch flavor at the 9% fat level. Decr cook yields (1-2%) were noted for MWMS, RIFL and TADE at the 5% level, however, by increasing the smokehouse relative humidi >50% this problem could likely be corrected.

Claus and Hunt (1991) manufactured bolognas with 10% fat and 2 to 5% sugar beet pulp, pea and oat fiber, wheat and modified maize starch, and soy protein isolate and noted that they were darker, less firm and had greater cooking losses than a 30% fat co Fiber containing bolognas were less juicy and more grainy than the control, but modified waxy maize starch reduced vacuum purge also suggested that selective combinations of ingredients will likely be an effective means of improving the textural and proce characteristics of low-fat bologna.

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