PROCESSING OF MEAT TO MEAT CONSUMER DEMAND: THE DEVELOPMENT OF LOW-FAT GROUND PRODUCTS

D.L. Huffman
Department of Animal and Dairy Sciences
Auburn University
Auburn, AL 36849
United States

Summary

A chronology of the development of low-fat ground beef and pork sausage has been presented. Early research was largely with only modest reduction in fat content and generally involved addition of a soya product. Increasing consumer awareness of fat in the diet during the 1980s resulted in an increase in interest by the scientific community to develop technologies for a significant reduction of fat in ground meat products. Impetus for change came from the funding of projects by the National Livestock and Meat Board, Beef Industry Council and the Pork Industry Group.

Technology has been developed which includes the addition of non-meat additives to low-fat formulations. These technologies have received in-depth scientific scrutiny for biochemical, physical and sensory properties. Studies have been completed on oxidative and microbiological stability during fresh or frozen storage. Furthermore, consumer studies have documented the viability of the proposed concepts. Finally, the developed technologies have been fully transferred to the private sector and are being utilized in the retail, restaurant and institutional industries. Acceptance by the U.S. Department of Agriculture (USDA) of developed technologies for use in the children nutrition (school lunch) program has been realized and the USDA is currently evaluating new technologies.

Despite the body of data presented here, this is a dynamic area and further research is needed on non-meat ingredients in low-fat ground meat products.

Introduction

The nutritional quality of the food supply has emerged as a major concern of consumers, with dietary fat and calories from fat among the most important concerns of consumers. As consumers reduce the fat and caloric content of their diets, they select food products that contain less fat, and these attitudes are reflected in their meat selections. The meat industry, as well as the allied food service and retail industries, are addressing these consumer concerns.

Ground meat composition

Over seven billion pounds of ground beef products and one billion pounds of fresh pork sausage products are consumed annually in the United States. Ground beef represents approximately 43% of the total fresh beef consumption (AMI, 1990). Ground beef products generally contain between 20 and 30% fat. Fresh pork sausage products are generally much higher in fat content.

Consumer attitudes about fat

Food consumption patterns have changed dramatically in the last two decades. Trends indicate a shift in consumption of fats, with a decrease in visible, separable fat consumption, and an increase in the intake of low-fat animal products such as fish and low-fat milk (NRC, 1988). In a recent consumer study, over two-thirds of consumers surveyed had some concerns about health with one of their major concerns being the amount of fat in their diets (Yankelovich, 1985). In a 1987 survey, a majority of consumers indicated that they were limiting the amount of fat, calories and cholesterol in their diets (Burke Marketing Research, 1987). This survey also found that consumers were responding positively to leaner beef cuts with the perception that these cuts were more healthy. Similar findings were reported from a National Consumer Retail Beef Survey where it was reported that consumers perceived closely trimmed (0.3 in external fat) or completely trimmed beef cuts as being lower in fat and cholesterol than cuts with 0.5 in of external fat (Cross *et al.,* 1980). The National Restaurant Association conducted a consumer attitude and behaviour study which indicated that at least half of those interviewed were making a conscious effort to restrict their consumption of fat and cholesterol (NRA, 1986).

The need for fat reduction in the diet has been further emphasized by the recommendations of the American Cancer Society (ACS, 1984) and the American Heart Association (AHA,1986) to restrict calories from fat to less than 30% of total caloric intake. Based on a study by the Food Marketing Institute (FMI, 1990), consumer concerns for fat content in food products increased from only 9% in 1983 to 46% in 1990. A similar trend was shown for concern about cholesterol content of foods. However, concern for calorie content showed only a modest increase from 1983 to 1990 (FMI, 1990).

Low-fat ground beef

The simple reduction of fat would be the most efficient method of producing low-fat ground beef products. However, the palatability of ground beef is directly related to fat content. Early research (Glover, 1968; Law *et al.,* 1965; Huffman and Powell, 1970; Mize, 1972; Cross *et al.,* 1975) indicated that sensory properties of higher fat ground beef formulations were more desirable than those of reduced fat products. The foregoing studies had as their major objective the interaction of soya products and sensory properties of ground beef. The variation in fat content in these studies was in the range of 15 to 35%. The first study reported by Glover (1968) included consumer studies in Texas (150 households each in Dallas and Houston) comparing 15, 20, 25 and 30% fat with no non-meat additives. Generally the panellists preferred the product containing 20% fat. The second study reported by Glover (1968) involved 250 households in Birmingham, Alabama and compared two fat levels (15 and 20%) and 0, 1 and 3% added soya. These consumers did not discriminate between the levels of fat but indicated a preference for products containing a small amount of added soya.

The study of Huffman and Powell (1970) compared three fat levels (15. 25 and 35%) with and without 2% added soya. Trained sensory panellists preferred the lower levels of fat (15 or 25%) with 2% added soya. A major research report edited by Mize (1972) summarized consumer research (649 households) from five states (Alabama, Georgia, Louisiana, Mississippi and Texas). All products (15, 25 and 35% fat, with and without 2% soya) were prepared in one processing plant. The presence of soya in all three levels of fat increased the consumer acceptance scores. Flavour scores were highest for ground beef containing 15% fat and 2% soya which confirmed studies with trained sensory panellists using identical formulations (Huffman and Powell, 1970).

Waite *et al.,* (1972) compared ground round, ground chuck and ground beef with 4, 17 and 28% fat respectively and found the untrained panellists preferred the ground chuck product containing 17% fat over low-fat (4%0 or high-fat (28%) products. An institutional consumer study reported by Cross et a. (1975) compared

22 and 25% fat products containing 0, 12.5 and 20% textured soya protein (TSP) in an institutional setting. They indicated that sensory properties did not differ between fat levels or levels of added TSP.

The effect of TSP on sensory properties of patties containing 15, 20, 25 and 30% fat and 0, 15, 20 and 25% TSP was studied by Drake and co-workers (Drake *et al.*, 1975) who concluded that there was no interaction between TSP and fat levels and any addition of TSP resulted in lower quality and acceptance ratings regardless of fat content.

Ono *et al.* (1985) reported on nutrient retention studies of ground beef patties containing approximately 18, 22 and 27% fat and concluded that for most nutrients, differences due to fat level, were too small to be of practical nutritional significance. The principal chemical components of ground beef are protein, moisture and fat. Since protein is relatively consistent, the determination that an inverse relationship existed between fat and moisture (Kregal *et al.*, 1986; Huffman and Egbert, 1990; Troutt *et al.*, 1992a) was expected.

Reports in the literature on fat reduced ground beef formulations, prior to the reports of Neale (1989) and Huffman and Egbert (1990), did not address the issue of significant fat reduction to less than 10% in ground beef systems. In 1988, the National Livestock and Meat Board, Beef Industry Council funded projects at three universities (Auburn University, Kansas State University and the University of Illinois) and two private laboratories (ABC Research Corporation, Gainesville, FL and Webb Technical Group, Inc., Raleigh, NC). The broad objective of these projects was to develop a low-fat (less than 10% fat) ground beef product that had physical and sensory properties comparable to 'typical' ground beef.

Studies reported by Neale (1989) indicated that ground beef patties containing approximately 20% fat had the highest sensory ratings among patties containing 5, 10, 15, 20, 25 and 30% fat. This finding has been confirmed by other studies (Huffman and Egbert, 1990; Troutt *et al.*, 1992b). Huffman and Egbert (1990) reported that overall acceptability was highly correlated ($r=0.69$; $P<0.05$) to beef flavour intensity. This research confirms that of Berry and Leddy (1984) in which it was found that 19% fat ground beef had greater beef flavour intensity that 14% fat ground beef. They also found a decline in flavour intensity in ground beef with higher fat content (24%). Several researchers have shown that as fat content of ground beef decreases, there is a significant decrease in product juiciness and tenderness (Kendall *et al.*, 1974; Cross *et al.*, 1980; Berry and Leddy, 1984; Kregel *et al.*, 1986). Research conducted at Auburn University (Huffman and Egbert, 1990); Neale, 1989; and Kansas State University (Troutt *et al.*, 1992b) with patties ranging in fat content from 5 to 30% found that patties containing 10% fat or less had a denser structure and were generally less acceptable to panellists than patties containing higher levels of fat. These researchers concluded that low-fat textural properties must be improved in order to have palatability similar to ground beef patties containing 20 to 30% fat.

A study was designed to evaluate compositional properties and overall consumer acceptance of ground beef patties containing 10% fat (Liu *et al.*, 1991a) from beef or partially hydrogenated plant oils (corn, cottonseed, palm, peanut and soybean). Addition of hydrogenated plant oils had little effect on composition of raw or cooked patties. Those containing hydrogenated corn or palm oil were not different ($P>0.05$) from all-beef patties in cooking loss or overall acceptability. These researchers concluded, therefore, that substitution of hydrogenated oils for beef fat in production of lean ground beef patties may be feasible.

There has been considerable interest in the use of soy protein in low-fat ground beef formulations in recent years. A study by Liu *et al.* (1991b) had the objective of determining the effect of addition of soy protein isolate, frozen TSP isolate and hydrogenated soy oil on compositional, physical, microbial and sensory stability of low-fat ground beef. They concluded that the use of soy protein and oil emulsion was an acceptable method for incorporation of oil into ground beef products. Sensory panellists found that low-fat ground beef products with 25% frozen TSP isolate (10% fat from beef) had as intense a beef flavour ($P>0.05$) as an all-beef control product. Addition of soybean oil and/or isolated soy protein decreased ($P<0.05$) lipid oxidation and meat pigment discolouration. Soy protein and/or oil addition did not affect the microbial properties of the low-fat ground beef formulations. The popular literature and meat trade journals contain numerous reports of successful use of soy protein products in the manufacture of low-fat ground beef products. It should also be noted that the trade journals and popular press have documented studies with oat bran and oat fibre that have resulted in successful low-fat ground beef products being marketed. To date, however, these studies have not been published in peer reviewed journals.

Berry (1992) studied the sensory properties of extremely low fat (0, 4, 8, 12, 16, 20%) patties cooked under varying conditions and concluded that alterations in processing and cooking would probably be necessary to achieve acceptance of extremely low-fat patties.

It is evident from the above studies that production of low-fat ground beef products through simple fat reduction would result in a substantial decrease in product palatability, flavour intensity, juiciness and tenderness.

Several studies (Huffman and Egbert, 1990; Kasaback, 1991; Roth *et al.*, 1990) have reported that overall palatability can be improved by final grinding through a fine (2 to 3 mm) plate. Research conducted at the University of Illinois (Roth *et al.*, 1990) indicated that pressure applied during processing had a profound effect on textural properties of ground beef patties. The implications of these findings are that care should be taken during forming to keep pressure on patties at a minimum to avoid compaction.

Studies were conducted (Huffman and Egbert, 1990; Kasaback, 1991) to evaluate the effect of various flavour-related additives (e.g., black, white and red pepper; monosodium glutamate; onion and garlic powders; flaked salt; hydrolyzed vegetable protein [HVP]) on the enhancement of beef flavour intensity in low-fat ground beef. Results indicated that use of a 2:1 ratio of salt to HVP at concentrations of 0.25% and 0.125% respectively produced a beef flavour intensity similar to the 20% fat control product.

With the appropriate flavour modification in place, studies at Auburn University concentrated on improvements in the juiciness and tenderness of the product (Huffman and Egbert, 1990; Egbert *et al.*, 1991b; Bullock *et al.*, 1993). It was felt that juiciness and possible tenderness could be improved through the retention of moisture within the product. The food gum carrageenan was selected for moisture retention purposes on the basis of its ability to form a complex water and protein. There are three basic types of carrageenan: kappa, iota and lambda. Each of these carrageenans impart different properties to the products to which they are added.

Iota carrageenan's greatest function in a meat system, unlike other binders that function to bind meat pieces together, is that of moisture retention. Iota carrageenan also has various other intrinsic properties which are beneficial in the production of low-fat ground beef. Some, but not all, iota carrageenans exhibit cold solubility, whereas kappa does not. Some functionality is achieved with iota carrageenan at low temperature, at higher concentrations. The cold solubility of some iota carrageenans enhance the machinability of low-fat ground beef. Iota carrageenans have very good freeze/thaw stability (compared to kappa or lambda) which is essential in the commercial manufacturing of beef patties. Not only are carrageenans not alike, but not all iota carrageenans are alike. Therefore, it was essential that the proper blend(s) of iota carrageenans be used to successfully produce high quality low-fat ground beef. Various blends and concentrations of carrageenan were evaluated in the low-fat ground beef product (Egbert *et al.*, 1991). Juiciness and tenderness scores similar to those of the 20% fat control were achieved through the addition of 0.5% of an iota carrageenan and 10% water to the low-fat product. With greater moisture retention it was necessary to make further adjustments in the concentrations of salt and HVP (0.4 and 0.2% respectively).

Bullock *et al.* (1993) investigated nine different water binding systems: five different types of carrageenan (Viscarin SD 389, Viscarin ME 389, Gelcarin GP 379, 50/50 ME 389 and GP 379, and Gelcarin ME 621) and a combination of xanthan/locust bean gum (pea flour, algin and modified food starch). The only significant differences ($P<0.05$) in water holding capacities were between patties containing Viscarin ME 389 and patties containing algin. Sensory panellists found only Viscarin ME 389 patties to be less juicy and tender than the control (Viscarin SD 389) patties while patties containing algin were more ($P<0.05$) tender than patties from other treatments. There were no difference ($P>0.05$) between treatments for off-flavour or perceptible connective tissue. Patties containing algin received the lowest flavour intensity scores ($P<0.05$). This study confirmed the fact that the *AU Lean*[tm] formulation (Viscarin SD 389 [FMC Corp.], HVP and encapsulated salt) provided the most acceptable low-fat ground beef pattie.

Troutt *et al.* (1992b) determined that added ingredients have potential for improving palatability of 5 to 10% fat ground beef, especially effects on the firmer, dryer, more crumbly products typical of low-fat patties. A three-way combination of polydextrose, potato starch and either sugar beet, oat or pea fibre reduced firmness, cohesiveness, cohesiveness of mass and sustained cohesiveness of patties with 5 and 10% fat such that they were similar to 20% fat patties.

These ingredients resulted in slightly reduced beef flavour intensity, but flavour scores not significantly different from 20 or 30% fat controls. Juiciness traits of low-fat products were reduced by the added non-meat ingredients.

As stated earlier, the major objective in the development of low-fat (<10% fat) ground beef products was to produce a low-fat product that was as organoleptically acceptable as ground beef containing 20% fat. An example of the results from trained sensory panel evaluation of three beef pattie formulations (Egbert *et al.*, 1991) indicate that the developed product (*AU Lean*) was more juicy and tender than 20 or 8% fat all-beef patties ($P<0.05$), with 8% fat patties being rated lowest for juiciness ($P<0.05$) (Table 1). Lower juiciness scores were expected for low-fat patties. However, this sensory problem was corrected in *AU Lean* through the incorporation of iota carrageenan and water. Mealiness, a common problem in low-fat ground meat products, was prominent for 8% fat, all-beef patties. Sensory panellists found these patties to be more mealy than 20% fat and *AU Lean* patties (P<0.05). Less connective tissue was detected by sensory panellists in *AU Lean* patties than in all-beef patties (P<0.05). Improvements in the amounts of detectable mealiness and connective tissue were probably also related to addition of carrageenan and water. A final sensory trait which is highly correlated to consumer overall acceptability is flavour intensity (Huffman and Egbert, 1990). Sensory panellists rated *AU Lean* patties higher in beef flavour intensity than the 20% fat or 8% fat all-beef patties (P<0.05). Salt and HVP addition was responsible for the enhanced flavour intensity of the *AU Lean* product.

Table 1. Sensory and physical properties of cooked low-fat beef patties.

Trait[z]	*Treatment* 20% fat	8% fat	AU Lean[tm]	*SEM*[y]
juiciness	5.8^{w}	4.6^{v}	6.7^{x}	0.12
tenderness	5.6^{w}	5.2^{w}	6.6^{x}	0.22
connective tissue	6.8^{w}	6.8^{w}	7.3^{x}	0.06
mealiness	6.5^{w}	6.1^{v}	6.9^{x}	0.05
beef flavour intensity	5.2^{w}	4.6^{w}	6.4^{x}	0.16
shear force (kg/g)	3.5^{v}	4.4^{x}	4.0^{w}	0.06

[z] Juiciness, tenderness, connective tissue, mealiness and beef flavour intensity were rated on an 8-point scale where 1 = extremely dry, extremely tough, abundant, abundant and extremely bland and 8 = extremely juicy, extremely tender, none, none and extremely intense respectively.
[y] SEM = Standard error of the mean.
[xwy] Means within a row with different superscripts differ (P<0.05).

Low-fat patties were manufactured using the same raw material sources and, therefore, compositional differences in the low-fat patties were the result of use of non-meat ingredients (Table 2). Raw *AU Lean* patties had a higher moisture content (P<0.05) and a lower fat and protein content (P<0.05) than 8% all-beef patties. Cooked *AU Lean* patties had a similar protein content to 20% fat patties due primarily to the retention of added moisture (P>0.05). Cholesterol content of cooked patties indicated that *AU Lean* pattie had a lower cholesterol content than 8% or 20% fat all-beef patties (P<0.05). Again, this was probably the result of addition of water to the product and resultant diluted cholesterol levels.

Distribution of calories from fat and protein in the cooked patties showed that *AU Lean* patties had a lower caloric content than 8% or 20% fat all-beef patties (P<0.05). Twenty percent fat beef patties had the greatest (P<0.05) caloric content with calories from fat accounting for 64% of total caloric content compared to *AU Lean* patties with 43% total calories from fat.

Low-fat patties (*AU Lean* and 8% fat) had lower (P<0.05) total cooking losses than 20% fat patties. This was as expected since much of the fat in higher fat patties is lost during the cooking process. Results from the evaluation of individual constituent losses during cooking showed no differences (P>0.05) in moisture and protein loss among the three products. However, fat losses were greatest (P<0.05) in 20% fat patties.

Table 2. Compositional properties of low-fat ground beef patties.

	Treatment			
	20% fat	*8% fat*	*AU Lean^{tm}*	*SEM^{z}*
Raw composition				
moisture (%)	60.5^{w}	70.8^{x}	72.6^{y}	0.30
fat (%)	21.5^{y}	8.1^{x}	7.2^{w}	0.18
protein (%)	17.9^{w}	20.7^{y}	19.1^{x}	0.08
Cooked composition				
moisture (%)	55.8^{w}	63.6^{x}	66.3^{y}	0.52
fat (%)	19.2^{y}	9.8^{x}	8.2^{w}	0.34
protein (%)	24.8^{x}	26.6^{y}	24.5^{x}	0.23
Cholesterol (mg/100g)	86.3^{y}	83.1^{y}	72.2^{x}	1.35

^{z} SEM = Standard error of the mean.
^{yxw} Means within a row with different superscripts differ (P<0.05).

Kramer shear force values of samples equilibrated to room temperature were poorly correlated to sensory panel tenderness scores. Twenty percent fat patties had the lowest (P<0.05) shear force value (Table 1) of the three formulations. This is in contrast to sensory tenderness scores where *AU Lean* patties were rated as most tender (P<0.05). Shear force values for *AU Lean* patties, however, were still lower (P<0.05) than 8% fat patties. Shear force differences between low-fat patties are again probably the result of addition of the carrageenan and water combination to *AU Lean* patties. No differences (P>0.05) were found among beef pattie treatments for tensile strength.

The morphology of the ground beef products discussed above (Egbert *et al.*, 1991) was examined by light and transmission electron microscopy before and after cooking. Fibre width decreased 10 to 15% upon cooking patties. In samples containing 8% fat with no additives, the bundles became closely pressed together after cooking. Particles of iota carrageenan were homogeneously distributed in the *AU Lean* product and the size and shape of the particles remained unchanged after cooking. These particles were similar in size and shape to the lipid droplets observed in cooked 8 and 20% fat patties. At the ultrastructural level, the particles had the morphological appearance of a gel or network. Based on the morphological observations of Dylewski (Egbert *et al.*, 1991):

- Given the similarity in size and shape of carrageenan particles in the *AU Lean* product to lipid droplets in the 8 and 20% products, it could be argued that the hydrated carrageenan might be similar in organoleptic perception to lipid droplets, and in that sense function as a replacement; and

(2) the carrageenan particles had the ultrastructural morphology of fully hydrated gels after cooking, and these gels probably help retain moisture within the system.

Low-fat ground beef technologies have been developed that have the desired sensory and physical properties. If developed low-fat ground beef systems are to be successful in the retail trade, there must be assurance that the addition of non-meat ingredients and water do not decrease storage stability during normal retail distribution. Therefore, a study was designed to determine the effect of low-fat ground beef production using water, carrageenan salt and hydrolyzed vegetable protein on the microbial growth and oxidative (colour and lipid) stability of low-fat ground beef during simulated retail distribution (Egbert *et al.*, 1992a). No differences were found in the aerobic plate counts, populations of psychrotophic bacteria or yeast and mould populations for low-fat carrageenan-based ground beef and a low-fat all-beef control. Retail display of the low-fat products in oxygen-permeable (aerobic) packaging resulted in greater product discoloration than that of products in oxygen-impermeable packaging. Colour stability of low-fat ground beef products decreased with increased storage time. Overall, few differences were found in oxidative stability and microbial populations of the low-fat products.

Further research at Auburn University (Egbert *et al.*, 1992b) had the objective of determining refrigerated storage stability of low-fat, carrageenan-based ground beef patties and to evaluate the effect of potassium lactate on the aerobic storage stability and sensory properties of these patties. Bacterial growth in low-fat carrageenan-based patties was not different from low-fat, all-beef patties, and was retarded through the use of 2 or 3% potassium lactate with no deleterious effect on the sensory properties. Low-fat, carrageenan-based patties underwent greater discoloration and lipid oxidation during refrigerated storage, probably as the result of sodium chloride promoted oxidation.

Dunkelberger and co-workers (Dunkelberger *et al.*, 1991a and 1991b) conducted a study to test consumer response to the developed low-fat ground beef product (*AU Lean*). They found a very positive response from consumers which suggests a strong potential for consumer acceptance of a lean product at the retail market.

Low-fat fresh pork sausage

More than a billion pounds of fresh pork sausage are consumed annually in the United States. Simple reduction of fat would be the most efficient method of producing low-fat fresh pork sausage. However, palatability of fresh pork sausage is directly related to fat content. Production of low-fat fresh pork sausage products through simple fat reduction would result in substantial decreases in product palatability, flavour intensity, juiciness and tenderness. To determine a "bench mark" for studies on low-fat fresh pork sausage, researchers at Auburn University (Egbert *et al.*, 1990) manufactured fresh pork sausage patties containing 10,20,30,40,50, and 60% fat and submitted samples to a 100-member untrained consumer-type panellists for evaluation. There was a linear increase in acceptability score from 10 to 40% with a sharp reduction in acceptability at 50 and 60% fat content. Based on this experiment, 40% fat was used as a control for further studies.

Researchers at the University of Georgia (Ahmed *et al.*, 1990) studied replacement of fat with water in fresh pork sausage containing 15, 25 and 35% fat. Results from this study suggest that some of the sensory properties associated with low-fat sausage could be reduced with the addition of water. Sensory panel ratings for tenderness, cohesiveness, flavour and overall palatability, as well as objective measures of shear force did not differ between sausages formulated to 35% fat with 3% added water and that formulated to 25% fat and 13% added water, nor between 25% fat-3% added water and 15% fat-13% added water. Therefore, pork sausage may be produced with 15% fat and desirable palatability maintained if added water is used to replace fat.

The overall objective of the study reported by Huffman *et al.* (1993) was to develop a low-fat (<10% fat) fresh pork sausage product that had sensory properties equal (or superior) to traditional fresh pork sausage patties. Efforts in low-fat (8% fat) fresh pork sausage focused on producing products with sensory characteristics similar to a control product at a higher fat level (40% fat). With the appropriate control defined, studies were implemented using the carrageenan-based technology developed for low-fat ground beef. It was found that overall palatability could be improved through the use of pork flavour enhancers in combination with a normal pork sausage seasoning blend. Desired juiciness, tenderness and textural properties of the low-fat sausage products were achieved through the addition of iota carrageenan and water to the low-fat pork. Evidence from these studies indicate that low-fat sausages formulated with 0.35% carrageenan and 20% added water provided sausage patties with significantly less fat, but with more desirable sensory characteristics than the control formulations. The developed low-fat fresh pork sausage patties have a 70% reduction in fat and a 46% reduction in calories when compared to traditional fresh pork sausage patties. Depending on the desired textural properties of the low-fat sausage product, further textural improvements (increased firmness) may also be achieved through the incorporation of oat fibre (Huffman *et al.*, 1992) or other non-meat additives such as texturized soy concentrate.

Two studies have been undertaken to determine the storage stability of low-fat fresh pork sausage. The first (Bradford *et al.*, 1993), had the objective of determining the effect of adding water and carrageenan to low fat (8% fat) fresh pork sausage during aerobic refrigerated (5-7°C) retail display and to determine the effects of adding potassium lactate on the sensory properties of such stored low-fat, carrageenan-based pork sausage. Bacterial growth in low-fat (8% fat) carrageenan-based patties was not different from low-fat control fresh pork sausage (8% fat) patties. Psychrotrophic and coliform populations in traditional fresh pork sausage patties (40% fat) were retarded through the use of 2% potassium lactate. Potassium lactate had no effect on sensory properties of the low-fat pork sausage pattie treatment. Low-fat carrageenan-based patties (8% fat) did not differ from low-fat control fresh pork sausage (8% fat) in percent discolouration during aerobic refrigerated storage. Bacterial growth in low-fat (8% fat) carrageenan-based sausage patties was not different from low-fat control fresh pork sausage (8% fat) patties. Psychrotrophic and coliform populations in traditional fresh pork sausage patties (40% fat) were retarded through the use of 2% potassium lactate. Potassium lactate had no effect on sensory properties of low-fat fresh pork sausage pattie treatments. Low-fat carrageenan-based patties (8% fat) did not differ from low-fat control fresh pork sausage (8% fat) in percent discolouration during aerobic refrigerated storage.

The second study (Ho *et al.*, 1993) dealt with frozen storage stability of low-fat fresh pork sausage. Three formulations of fresh pork sausage were manufactured:

40% fat product; low-fat product containing 0.4% carrageenan; and low-fat product containing 0.4% carrageenan and 1.5% soy protein concentrate. These treatments were evaluated for frozen storage stability when the following antioxidant treatments were used: no antioxidant; BHT, propyl gallate and citric acid blend; and rosemary extractive. Two packaging were used: polyethylene (PE-bag) and vacuum packaging. Sensory evaluations, visual colour appraisals, TBARS (oxidative rancidity) tests and Hunter colour values ('L', 'a'. 'b') were determined at four-week intervals over 16 weeks of frozen storage. Low-fat fresh pork sausage (carrageenan-based) without antioxidants had acceptable sensory properties and TBARS values throughout 16 weeks frozen storage when vacuum packaged. Oxidative rancidity was retarded in regular high-fat products when antioxidants and vacuum packaging were used. Products packaged in PE-bags had superior overall colour scores and Hunter colour 'a' values ($P<0.05$) to vacuum packaged products prior to 8 weeks storage. Vacuum packaging tended to maintain better red colour in sausage products than PE-bag packaging with extended periods of storage. Antioxidants did not have an effect on colour ($P>0.05$). Colour of low-fat sausage products was more stable than that of regular high-fat products during frozen storage. The natural antioxidant (rosemary extractive) was as effective as the blend of BHT, propyl gallate and citric acid ($P<0.05$). Vacuum packaging was superior to PE-bags for control of lipid oxidation in fresh pork sausage products during frozen storage ($P<0.05$).

References

ACS. 1984. Nutrition and cancer, cause and prevention. An American Cancer Society special report. Ca-C *Cancer Journal for Clinicians.* 34(2):121.

AHA. 1986. *Dietary guidelines for healthy adult Americans.* American Heart Association. Circular. 74:1465A.

AMI. 1990. *Meat facts '90.* American Meat Institute. Washington, D.C.

BERRY, B.W. 1992. Low fat level effects on sensory, shear, cooking and chemical properties of ground beef patties. *J. Food Sci.* 57:537-540.

BERRY, B.W., and LEDDY, K.F. 1984. Effects of fat level and cooking method on sensory and textural properties of ground beef patties. *J. Food Sci.* 49:870-875.

BRDFORD, D.D., HUFFMAN, D.L., EGBERT, W.R., and JONES, W.R. 1993. Low-fat fresh pork sausage pattie stability in refrigerated storage with potassium lactate. *J. Food Sci.* (In press).

BULLOCK, K.B., HUFFMAN, D.L., EGBERT, W.R., MIKEL, W.B., BRADFORD, D.D., and JONES, W.R. 1993. Sensory and chemical evaluation of alternative water binding systems in low-fat ground beef. *J. Food Sci.* (Submitted).

BURKE MARKETING RESEARCH. 1987. *The Consumer Climate for Meat Study.* Prepared for the National Livestock and Meat Board, Chicago, IL, and the American Meat Institute, Washington, D.C.

CROSS, H.R., BERRY, B.W., and WELLS, L.H. 1980. Effects of fat level and source on the chemical, sensory and cooking properties of ground beef patties. *J. Food Sci.* 45:791-793.

DRAKE, S.R., HINNERGARDT, L.C., HLUTER, R.A., and PRELL, P.A. 1975. Beef patties: The effect of soy protein and fat levels on quality and acceptability. *J. Food Sci.* 40:1065-1067.

DUNKELBERGER, J.E., SUMMERFORD, D.H., HUFFMAN, D.L., and EGBERT, D.P. 1991. Development of low-fat ground beef. *Food Technol.* 45(6):64, 66-68, 70-71, 73.

EGBERT, W.R., HUFFMAN, D.L., CHEN, C.M., and JONES, W.R. 1992a. Microbial and oxidative changes in low-fat ground beef during simulated retail distribution. *J. Food Sci.* 57:1269-1274, 1293.

EGBERT, W.R., HUFFMAN, D.L., BRADFORD, D.D., and JONES, W.R. 1992b. Properties of low-fat ground beef containing potassium lactate during aerobic refrigerated storage. *J. Food Sci.* 57:1033-1037.

FMI. 1990. *Food Marketing Survey - 1990.* Food Marketing Institute. Washington, D.C.

GLOVER, R.S. 1964. Consumer acceptance of ground beef. Proc. Reciprocal Meat Conf. 21:353-358.

HO, C.P., HUFFMAN, D.L., and EGBERT, W.R. 1993. Frozen storage stability of low-fat fresh pork sausage. Presented at the 53rd Annual Meeting of Inst. of Food Technologists. Chicago, IL. (Abstract).

HUFFMAN, D.L., and POWELL, W.E. 1970. Fat content and soy level effect on tenderness of ground beef patties. *Food Technol.* 24:100-101.

HUFFMAN, D.L., and EGBERT, W.R. 1990. *Advances in lean ground beef production.* Alabama Ag. Expt. Station. Bull. 606.

HUFFMAN, D.L., EGBERT, W.R., CHEN, C.M., and DYLEWSKI, D.P. 1992. Development of lean pork sausage products. *Cereal Foods.* 37(6):439-442.

HUFFMAN, D.L., CHEN, C.M., EGBERT, W.R., and BRADFORD, D.D. 1993. *Low-fat fresh pork sausage production.* Alabama Ag. Expt. Station. Bull. 620.

KASABACK, C.A. 1991. *Developments in lean ground beef technology.* M.A. thesis. Auburn University. Auburn, AL.

KREGEL, K.K., PRUSA, K.J., and HUGHES, K.V. 1986. Cholesterol content and sensory analysis of ground beef as influenced by fat level, heating and storage. *J. Food Sci.* 51:1162-1165, 1190.

LAW, H.M., BEESON, M.S., CLARK, A.B., MULLINS, A.M., and MURRA, M.G. 1965. *Consumer acceptance studies: II. Ground beef of varying composition.* Louisiana State University. Agr. Expt Station. Bull. 597.

LUI, M.N., HUFFMAN, D.L., and EGBERT, W.R. 1991a. A research note: Replacement of beef fat with hydrogenated plant oil in lean ground beef patties. *J. Food Sci.* 56:861-862.

LUI, M.N., HUFFMAN, D.L., EGBERT, W.R., McCASKEY, T.A., and LUI, C.W. 1991b. soy protein and oil effects on chemical, physical and microbial stability of lean ground beef patties. *J. Food Sci.* 56:906-912.

MIZE, J.J. 1972. *Factors affecting meat purchases and consumer acceptance of ground beef at three levels with and without soyabits.* Southern Coop. Series Bull. 173.

NEALE, M.G. 1989. *An innovative approach to lean ground beef production.* M.S. thesis. Auburn University. Auburn, AL.

NRA. 1986. 1987 *National Restaurant Association Food Service Industry Forecast.* National Restaurant Association. Washington, D.C.

NRC, and NATIONAL RESEARCH COUNCIL. 1988. Current trends in the consumption of animal products. In: *Designing Foods: Animal Product Options in the Marketplace.* National Academy Press. Washington, D.C. p.p.18-44.

ONO, K., BERRY, B.W., and PAROCZAY, E. 1985. Contents and retention of nutrients in extra lean, lean and regular ground beef. *J. Food Sci.* 50:701-706.

ROTH, D.M., McKEITH, F.K., McLAREN, D.G., BECHTEL, P.J., and NOVAKOFSKI, J. 1990. Effect of temperature, pressure, particle size, mixing time and fat content on the textural properties of ground beef. Proc. Reciprocal Meat Conf. 43:171. (Abstract).

TROUTT, E.S., HUNT, M.C., JOHNSON, D.E., KASTNER, C.L., KROPF, D.H., and STRODA, S. 1992a. Chemical, physical and sensory characterization of ground beef containing 5 to 30 percent fat. *J. Food Sci.* 57:1-29.

TROUTT, E.S., HUNT, M.C., JOHNSON, D.E., KASTNER, C.L., and KROPF, D.H. 1992b. Characteristics of low-fat ground beef containing texture modifying ingredients. *J. Food Sci.* 57:19-24.

WAITE, J.R., HUFFMAN, D.L., and ADAMS, J.R. 1972. Ground beef quality, price affect consumer preference. Alabama Ag. Expt. Station. *Highlight of Ag. Research.* 19(2):13.

YANKELOVICH. 1985. *The Consumer Climate for Meat Products.* Prepared for the American Meat Institute, Washington, D.C. and the National Livestock and Meat Board, Chicago, Il. Yanelovich, Shelly and White, Inc.