ELECTRICAL STIMULATION AND HOT PROCESSING: EFFECTS ON COOKING AND SENSORY PROPERTIES, COLOR AND MICROBIAL COUNT OF GROUND BEEF WITH THREE FAT LEVELS

by

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INTRODUCTION

Ground beef is one of the most popular meat products sold in retail markets (Anonymous, 1971). Several investigators have reported on the effect of fat level on consumer acceptance of ground beef (Cole et al., 1960; Law et al., 1965, 1971; Kaiser et al., 1970; Kendall et al., 1974). According to Szczeniak (1968) and Simmons and Pixson (1975), consumers are more likely to reject meat because of toughness than for lack of flavor or juiciness. Tenderness of ground beef is related to its fat content (Cole et al., 1960; Kaiser et al., 1970; Huffman and Powell, 1970; Kendall et al., 1974; Cross et al., 1975).

A number of procedures have been developed for increasing tenderness of meat. A method of tenderization recently researched is electrical stimulation (ES) of carcasses on the kill floor. Research has shown that tenderness is the eating quality most affected by ES of beef and lamb carcasses (Davey et al., 1976; Grusby et al., 1976; Savell et al., 1976, 1978a, b; Cross et al., 1979). Carcass stimulation followed by hot boning (processing of carcasses soon after slaughter) results in reducing the chilling and aging period from 10 to 20 days to two days, and saves cooler space (Gilbert et al., 1977).

Tenderness and juiciness of ground beef prepared from hot boned carcasses were rated 10 to 20% greater than tenderness and juiciness of meat from carcasses processed by conventional cold boning (Anonymous, 1979a). However, data from research done at the Meat Science Research Laboratory, USDA (Anonymous, 1979b) indicated that ES and hot boning of

mature beef carcasses had no practical effect on sensory properties of ground beef.

Because of the different conditions of temperature and time at which ES and hot boning of beef carcasses are performed, the microbial quality of beef prepared by electrical stimulation and/or hot boning was studied by Emswiler and Kotula (1978). They reported that the bacteriological quality and shelf life of ground beef from hot boned carcasses were equal to or better than those of ground beef prepared from chilled carcasses. Moreover, Raccach and Henrickson (1978) reported that the shelf life of refrigerated ground beef from electrically stimulated, hot boned carcasses was prolonged by 3 days as compared to the control.

Color is a prime judgment of quality in meat products. The consumer selects a meat product primarily on leanness, and then on appearance and freshness, with the latter judgment based primarily on brightness of color (Rhodes et al., 1955; Seltzer, 1955). Fresh meat color seems to be dependent on the type of light used in the display case. Kraft and Ayres (1954) observed a steady change from bright red to dull red during the first two days exposure of fresh beef to 30 to 40 ft-candles of fluorescent light.

Setser et al. (1973) studied the oxidation of meat pigments in intact fresh bovine semitendinosus muscle at 254, 405, and 577nm radiant energy in a model system with 0, 20 and 100% oxygen. They found significantly more MetMb in the samples exposed to radiant energy than in control samples. Cutaia and Ordal (1964) studied the effect of the amount of fat on the rate of MetMb formation and its conversion to Mb in anaerobically packaged ground beef. They reported that as the amount of

fat in the ground beef (0 to 40%) was increased, the rate of MetMb formation and its conversion to Mb increased.

No research reports were found that were concerned with cooking and sensory properties, microbial counts, and color stability of ground beef with three levels of fat prepared from electrically stimulated, hot processed muscle. Therefore, a study was proposed to: (1) identify and compare cooking and sensory properties, and related objective measurements of ground beef containing three levels of fat prepared from electrically stimulated, and hot boned or conventionally chilled and fabricated muscle and (2) investigate microbial counts and color stability of the raw ground beef products using a model system.

REVIEW OF LITERATURE

Electrical stimulation

Background information. In the 1960's the discovery that muscle shortening was a major cause of meat toughness led to meat scientists taking a closer look at the postmortem treatments that could improve the eating quality of meat. In pre-rigor meat, muscle shortening is caused by chilling the carcass too soon and extensively after slaughter, which is known as "cold shortening"; or by rapid freezing and thawing ("thaw shortening"). The phenomenon known as "cold shortening" occurs when pre-rigor muscles (above pH 6.0) are chilled to a temperature below 8°C (Chrystall, 1976). Because the practical significance of cold shortening has been confirmed in extensive studies in a number of laboratories, and because chilling has been used extensively to preserve meat, the meat processor has tried to find different ways to avoid the problem of cold shortening. An alternative for increasing tenderness and/or preventing

cold shortening may exist in the form of electrical stimulation of the carcass shortly after slaughter.

Electrical stimulation, a method of hastening rigor development, consists of the stimulation of the carcass with an electrical stimulus directly after slaughter or following the dressing process. Smith et al. (1977b) stated that the use of electrical stimulation to increase meat tenderness is not a new idea; its use for this purpose was first suggested by Benjamin Franklin in 1749, who determined that electrical shocking of turkeys enhanced tenderness.

Mechanism of action. The mechanism by which electrical stimulation works to improve tenderness has not been elucidated. Those who have worked most extensively with electrical stimulation of carcasses (Locker et al., 1975; Chrystall and Hagyard, 1976; Davey et al., 1976) have attributed its effect in enhancing tenderness to prevention of "cold shortening". On the other hand, other investigators (Smith et al., 1977a; Savell et al., 1977; Moeller et al., 1976) suggested that tenderization derived from electrical stimulation may result from enhanced activity of the autolytic enzyme fraction of muscle in treated carcasses or sides. A rapid decrease in muscle pH may hasten rupture of lysosomal membranes, releasing proteolytic enzymes at a time when muscle temperature is still high, thereby enhancing the rate or denaturation of autolytic proteolysis. In addition, Savell et al. (1978b) suggested that electrical stimulation may improve tenderness by physical disruption of the muscle fibers and the formation of contracture bands throughout the myofibers and not by prevention of cold shortening.

Stimulation condition. From the literature reviewed, it is evident that there is a lack of uniformity in the conditions used for application of electrical stimulation. New Zealand researchers (Chrystall and Hagyard, 1976; Davey et al., 1976; Gilbert and Davey, 1976; Gilbert et al., 1977), working on electrical stimulation of lamb and beef carcasses, used electrical pulse of alternating polarity with the following characteristics: 3600 volts on open circuit with less than 30 cycles per sec with continuous shocks for two minutes. In the United States, researchers (Grusby et al., 1976; Smith et al., 1977a, b; Savell et al., 1976, 1977, 1978a, b, c; Bowling et al., 1978) have used a much lower voltage (100-450 volts), 60 cycles per sec AC with intermittent shocks over a 60 sec period. In addition, Bendall et al. (1976) used voltages as high as 700 V, 25 cycles per sec DC with continuous shock for a period of two minutes. They reported that with 700 volts, optimal effects were obtained. There was an increase in the fall of pH to 6.0 within one hour of slaughter in undressed carcasses. Similar results were obtained with dressed carcasses and sides, after allowing for the 50 min or so lost in dressing.

Bendall et al. (1976) pointed out that the voltage of stimulation had a highly significant effect on the immediate pH fall during stimulation and on the subsequent rate of fall. Smith et al. (1978) reported that electrical stimulation (100 volts) increased tenderness of beef by 12 to 15% as compared to the control. However, the prevention of cold-shortening (as determined by relative sarcomere length) did not explain all of the tenderization effects achieved by electrical stimulation. This suggested that enhanced autolytic proteolysis may also be involved.

Shaw and Walker (1977) studied the effect of low voltage stimulation of beef carcasses on muscle pH. They found that high voltages were not necessary to accelerate glycolysis and that voltages in the range of 20 to 110 were as effective in accelerating glycolysis as were voltages in excess of 1000. They reported that a pH of 6.0 was reached within one hour of slaughter in dressing carcasses. Savell et al. (1977) reported that stimulation of beef carcasses with low voltage (100) improved tenderness. Bouton et al. (1978) confirmed the results of Savell et al. (1977) when using a low voltage stimulation (110V DC) on beef carcasses. They concluded that stimulation caused a marked increase in the tenderness of muscle and a significant increase in the rate of pH fall to 6.2 in one hour and 6.0 in four hours.

There is also some controversy about the time at which stimulation should be applied, either before dressing or after it. Chrystall (1976) working with lamb carcasses pointed out that the greatest benefit of any stimulation process could be obtained by stimulation as soon as possible after slaughter. Locker et al. (1975) shared that opinion. They stated that, in lamb, electrical stimulation did not accelerate rigor as effectively after dressing the carcass as it did immediately after slaughter. Devine (1976), working with beef sternomandibularis muscle, suggested that during delay (10 min to 2.5 hr) of stimulation, the muscle pH is already falling, so the additional fall during stimulation is not as great as in muscle stimulated earlier.

Bendall et al. (1976) compared the effect of electrical stimulation on undressed beef carcasses immediately after slaughter and dressed carcasses 50 minutes later. They found a similar rate of pH fall in the muscle stimulated immediately or 50 min after slaughter. They concluded

that the time after slaughter at which carcasses should be stimulated is a question of convenience, but it should not be delayed beyond 60 min, because its effectiveness falls off rapidly from that time onwards.

Effects on muscle pH. Fall in muscle pH is a measure of postmortem glycolysis, and by implication, of the onset of rigor mortis. Electrical stimulation of muscle has been shown to accelerate postmortem glycolysis (Karpatkin et al., 1964; Forrest and Briskey, 1967). Davey et al. (1976) working with electrically stimulated beef carcasses concluded that stimulation speeds glycolysis throughout the musculature of beef carcasses, and that rigor is reached well before the temperature has fallen to levels inducing cold shortening. Devine (1976) reported that the hastening of glycolysis in electrically stimulated carcasses occurs in two phases. The first phase takes place during stimulation with an initial fall of approximately 0.5 pH unit with two minutes stimulation. The second phase takes place following stimulation in which the muscle pH continues to fall approximately 50% faster than it does in unstimulated muscle. He also pointed out that the pH fall in both phases is more rapid at high, than at low temperatures, but only the initial fall is increased by a longer stimulus time. Bendall and Wismer-Pedersen (1962) suggested that the conditions of a high temperature and low pH obtained after stimulation of the carcass were ideal for rapid protein denaturation, which also has been associated with increased drip formation, particularly in pig muscle. Bendall et al. (1976) reported that drip loss (wateriness on the surface) of stimulated beef sides from the hind limb jointed 6 days after slaughter was not significantly greater than that from unstimulated carcasses.

Chrystall and Hagyard (1976) found that stimulation caused a marked acceleration of glycolysis compared with that in unstimulated carcasses. The ultimate pH in both stimulated and unstimulated lamb carcasses was about 5.5. Also, Smith et al. (1977b) reported that electrical stimulation of beef carcasses accelerated anaerobic glycolysis and the rate or extent of glycolysis was related to both color and firmness. However, electrical stimulation apparently did not affect USDA color scores or ultimate pH.

Effect on quality measurements. Accelerated glycolysis in postmortem muscle could affect certain quality factors such as lean color, texture, firmness and color uniformity. Savell et al. (1978a, c) reported that electrically stimulated beef sides had brighter color and less severe heat-ring formation than the non-stimulated sides. This is in agreement with the results of Cross et al. (1979), who found a significant reduction ($P < 0.05$) in the incidence of heat-ring by the use of electrical stimulation in beef muscle, and a significant improvement of lean color. Grusby et al. (1976) pointed out that electrical stimulation of U.S. Standard and Good grade carcasses apparently did not affect USDA color scores for meat (lamb, goat and beef) and did not produce heat-rings. They also suggested that beef carcasses ribbed 24 hr after slaughter may exhibit more desirable color and condition if they are electrically stimulated.

Effects on cooking properties. Savell et al. (1978a) reported that thawing loss, cooking loss, and cooking time were not affected by the use of electrical stimulation on beef carcasses. Savell et al. (1978c) found that electrically stimulated striploin stored for seven days had greater

percentage cooking losses than non-stimulated striploin stored for seven days or electrically stimulated striploin stored for 21 days. In addition, Cross et al. (1979) observed that cooking losses tended to be slightly higher for steaks from carcasses that were electrically stimulated than for steaks from non-stimulated carcasses. They postulated that the increase in cooking losses for the electrically stimulated sides could be caused by an increase of the rate of pH fall and a decrease of water holding capacity.

Effects on sensory properties. Davey et al. (1976) evaluated the eating quality of striploin, rump and topside beef cuts. They reported that tenderness was the eating quality most affected by stimulation ($P < 0.001$) on striploin unaged and aged. Grusby et al. (1976) found that electrical stimulation of beef carcasses, before chilling resulted in significant increase in tenderness of the muscle directly stimulated. Savell et al. (1976, 1978a, b) reported that steaks from electrically stimulated sides were scored more tender and had lower shear values than those from the non-stimulated sides. Also, Cross et al. (1979) reported that steaks from electrically stimulated sides were more tender ($P < 0.05$) and had lower shear force values than those from sides that were not electrically stimulated.

Texture and juiciness are the other eating characteristics likely to be associated with electrical stimulation. Davey et al. (1976) found no significant differences in either texture or juiciness scores for striploin cuts stimulated and unstimulated. Cross et al. (1979) reported higher ($P < 0.05$) juiciness scores for steaks from electrically stimulated sides than for steaks from non-stimulated sides. Conversely,

Savell et al. (1978b) found that a sensory panel scored steaks from electrically stimulated sides less juicy than those from the non-stimulated sides. Savell et al. (1976) evaluated the effect of electrical stimulation on beef carcasses graded U.S. Good and U.S. Standard. They found that there were no differences ($P < 0.05$) in juiciness ratings between the treated and untreated sides.

Savell et al. (1976, 1978b) reported that a sensory panel scored steaks (longissimus dorsi muscle) from electrically stimulated sides more flavorful than steaks from control sides. Cross et al. (1979) found that flavor scores for striploin steaks from electrically stimulated sides and non-electrically stimulated sides were not significantly different.

Savell et al. (1978a) found that mean sensory panel ratings for cooked longissimus muscle from electrically stimulated sides were more satisfactory in overall palatability ($P < 0.05$ to $P < 0.01$) than steaks from non-stimulated sides. Savell et al. (1978b) reported that overall palatability of beef samples from electrically stimulated sides stored for 21 days were more desirable than samples from electrically stimulated sides stored for 7 days.

Hot processing

The term hot processing is related to the processing of carcasses and their components soon after slaughter. It may be identified by terms: hot boning, anterior rigor excision, pre-rigor excision, accelerated processing, high temperature processing, pre-chill processing, processing prior to rigor and rapid processing.

Hot boning. Background information: Hot beef boning is not new, for man, when he first became a flesh eater consumed his kill in fresh

raw or fresh cooked form (Anonymous, 1979a). The processing of bovine carcasses soon after slaughter (hot boning) has several potential advantages. The economy of this process is reflected by the removal of waste fat and bone before chilling, thereby reducing the amount of chilling space by 30 to 35% per carcass. Boneless meat would have a more rapid cooling rate; refrigerated space would be saved, and the boneless product would lend itself to portion control and marketability (Henrickson et al., 1974).

The quality of beef resulting from boning the unchilled carcass has been evaluated (Schmidt and Gilbert, 1970; Kastner et al., 1973; Schmidt and Kemans, 1974; Henrickson et al., 1974; Henrickson, 1975; Kastner and Russell, 1975). Schmidt and Gilbert (1970) studied bovine muscle hot boned 2 hr after slaughter, vacuum packaged, and held at 15°C for 24 or 48 hr. They reported that a taste panel evaluated tenderness, juiciness, texture and general acceptability of the pre-rigor excised muscle as acceptable as the control held for 24 hr at 9°C, and in some instances it was superior. Also, they pointed out that the microbial spoilage was satisfactorily controlled in those samples.

Kastner et al. (1973) excised bovine muscle at 2, 5 and 8 hr post-mortem from carcasses stored at 16°C; the control was kept at 2°C for 48 hr before cold boning. They found that differences in reflected color values between hot and cold boned steaks were statistically significant for each holding period. However, the sensory panel did not find significant differences in the color of raw meat between hot and cold boned products. Moreover, nonsignificant differences were reported for cooking loss and flavor for hot and cold boned beef for each holding period.

Schmidt and Kemans (1974) evaluated the effect of hot boning and vacuum packaging versus cold boning of eight major bovine muscles. They reported that Warner Bratzler shear force determination and taste panel evaluation for flavor, juiciness, tenderness and overall acceptability failed to detect any significant differences between hot and cold boned steaks and roasts.

Taste panel studies conducted by Henrickson et al. (1974) evaluated the quality of beef muscle that had been boned and vacuum packaged after conditioning carcasses at 16°C for 3, 5 and 7 hours postmortem versus cold boned muscle chilled 48 hours at 1.1°C before fabrication. They reported that the panelists were able to distinguish differences ($P < 0.05$) in tenderness between the control and the unchilled excised longissimus dorsi at 7-hr holding period. They also stated that the panelists could distinguish significant differences in color between hot and cold boned muscle. A color preference was given to the cold boned muscle when compared to either the 3- or 5-hr excised product. Non-significant differences in cooking losses were reported between steaks for hot and cold boned muscle.

Kastner and Russell (1975) evaluated the quality of bovine muscle excised at 6, 8, or 10 hr postmortem and held at 16°C versus a control excised 48 hr postmortem and held at 2°C. Panel flavor evaluation indicated no significant differences between the hot and cold boned samples for each postmortem holding period. Although statistical differences were observed between corresponding color reflectance parameter means, a color panel evaluation of the same sample revealed no statistically detectable differences. Cross et al. (1979) evaluated the sensory and cooking properties of hot processed ground beef (21 ± 2% fat) prepared by

three grinding methods. They reported that the method of grinding had no significant effect on any palatability characteristic except flavor intensity. The authors also pointed out that when compared to the chilled patties, patties from the hot boned beef were significantly more tender, juicy and lost less water during cooking. Jacobs and Sebranek (1979) studied the differences in palatability, cooking characteristics and storage effects between conventionally processed ground beef patties and patties formulated immediately after slaughter (pre-rigor). They found less cooking losses for pre-rigor processed patties and higher consumer scores on flavor, tenderness, juiciness and overall acceptability for the pre-rigor patties. It was reported that tenderness and juiciness of ground beef from hot boned carcasses were rated 10 to 20% higher than meat from conventional processed carcasses. Cooking losses under controlled conditions were 33.85 and 41.06 for patties from hot boned and cold boned carcasses, respectively (Anonymous, 1979a).

Because of the different conditions of temperature and time at which the hot boning of beef carcasses is performed, the microbiological quality of beef prepared by hot boning was studied by Schmidt and Gilbert (1970), Henrickson et al. (1974), and Kastner et al. (1976). Henrickson et al. (1974) reported that on-the-rail boning procedure with low bacterial counts is more sanitary than the conventional method of fabrication. Kastner et al. (1976) found lower mesophilic and psychrotrophic counts in bovine carcasses using the hot boning procedure than with the conventionally chilled procedure. Fung et al. (1979) reported that meat processed by hot boning and stored for 14 days at 2.2°C was considered bacteriologically acceptable. Emswiler and Kotula (1978) reported that the bacteriological quality and shelf life of ground beef from hot boned

carcasses were equal to or better than those of ground beef prepared from chilled carcasses. Moreover, it was determined that the bacteriological quality of stored ground beef from hot-boned carcasses was equal or superior to that from chilled beef. A 30 to 40 days shelf life in a vacuum package at 32 to 34°F was obtained (Anonymous, 1979a).

Electrical stimulation and hot boning

Because rigor mortis is fully developed after three to four hours in carcasses that have been electrically stimulated, Chrystall and Hagyard (1976), Davey et al. (1976), and Gilbert and Davey (1976) postulated that the stimulated sides could be boned earlier when the carcasses are still warm without the risk of cold shortening. They found that early boning and freezing (40 min) after electrical stimulation does not affect eating qualities of bovine muscle. Furthermore, Gilbert et al. (1977) reported that hot boned cuts from stimulated carcasses aged before freezing attained a high uniform degree of tenderness.

More recently, research done at the Meat Science Research Laboratory, USDA at Beltsville, MD (Anonymous, 1979b) found that electrical stimulation and hot boning of mature beef carcasses had no practical effect on sensory properties of ground beef (21 ± 2% fat). However, they observed that ground beef prepared from lean meat boned at one or three hours postmortem appeared to be slightly more tender than meat boned 24 hours postmortem. Also, they observed that as the time before hot boning was increased from 1 to 3 or 24 hours, there were important increases in cooking losses.

Gilbert and Davey (1976) reported that the bacterial condition of beef was not changed by stimulation and early boning. Gilbert et al.

(1977) reported that the meat that had been hot processed (electrical stimulation and hot boning) was more wholesome than that processed by conventional chilling and aging procedures. Raccach and Henrickson (1978) reported that in refrigerated ground beef from electrically stimulated, hot boned carcasses the shelf life was prolonged by 3 days as compared to the control (4 to 5 vs 7 to 8 days, respectively). Also, they pointed out that non-pigmented Pseudomonas predominated in the flora spoilage of ground beef from electrically stimulated and hot boned carcasses and from control carcasses.

Consumption of ground beef

Ground beef is one of the most popular items on the retail market. It accounted for 31 percent of the total pounds of beef purchased during the period of a USDA survey of food consumption (USDA, 1955).

Law et al. (1965) reported that ground beef was a popular form of beef in the diets of families interviewed in a consumer survey in Bavton, La. Hamburgers were by far the most common form of ground beef served, with meat balls, meat sauce and meat loaf following in popularity. By 1971, about half the beef eaten in the United States was eaten in the form of hamburger, some 11.3 billion pounds of it a year, or a yearly average of about 55 pounds of hamburger for every man, woman and child in the country (Anonymous, 1971). By 1973 the United States Department of Agriculture reported that the consumption of ground beef had increased steadily over the past decade. Since 1970 the U.S. Department of Agriculture had purchased over 415 million pounds of ground beef for distribution to schools (USDA, 1973).

According to Federal definition, both "hamburger" and "chopped beef" must consist solely of fresh ground beef and no meat by products may be

added. It is also a product that varies highly in fat to lean composition and it may contain up to 30% fat by weight and still be labeled ground beef, chopped beef or hamburger (Federal Registrar, 1972).

Consumer acceptability of ground beef

The trend toward centralized processing and packaging of ground beef for distribution to retail outlets makes it important to know the quality attributes that consumers prefer in ground beef. Indeed, there is a genuine need among processors for scientific information on the most desirable fat content for maximum consumer acceptance. Several investigators have reported on the effect of fat level on consumer acceptance of ground beef. Cole et al. (1960) reported that laboratory and family taste panels rated ground beef with 15% fat less acceptable than ground beef with 25, 35 or 45% fat. Law et al. (1965, 1971) reported that consumers preferred ground beef with the relatively low fat content of 15 to 20%, and that consumers associated leanness with quality. Conversely, Kaiser et al. (1970) found that fat content had no influence on consumer acceptance of ground beef. Kendall et al. (1974) reported that overall-acceptability to a trained laboratory taste panel was similar for all ground beef products of 10, 20 or 30% fat.

Evaluation of ground beef properties

Fat and moisture determination in meat products. A number of laboratory methods can provide accurate knowledge of the fat content of meat products. Among those methods, the official method of the Association of Official Agricultural Chemists is the most widely accepted (A.O.A.C., 1975). Weir (1960) pointed out that the more precise methods for determining crude fat (or ether extract) in meat and meat products

involve extraction of fat from the dried sample with anhydrous ethyl ether or petroleum ether. The solvent is then removed by evaporation, and the residue is weighed and reported as fat. Kelly et al. (1953) compared the A.O.A.C. method with four rapid solvent extraction techniques. Results showed that the A.O.A.C. and modified Babcock method using sulfuric acid gave comparable results. Salwin et al. (1955) modified the Babcock method by using a perchloric acid-acetic acid mixture with the advantage of a rapid analysis (ca 30 min). Bellis et al. (1967) reported that the fat content in fresh ground beef could be determined by either the Hobart Fat Percent Indicator Method or the Soxhlet method with equal accuracy. However, the Hobart method was more rapid and economical and was sufficiently accurate in the range of 14 to 29% fat.

Engler and Bowers (1975) compared four liquid extraction methods: (1) ether extraction, (2) chloroform-methanol-water extraction, (3) predigestion with ether extraction and (4) thermal extraction (raw meat only) in a sample of raw and cooked ground beef. They concluded that for repeated analyses of raw meat, percentage lipid values obtained by ether extraction varied the least. Because of the precision and suitability of the method for laboratory conditions the authors recommended ether extraction for percentage lipid analyses when time for obtaining results is not a factor.

Moisture in meat is determined by drying a sample at a high temperature and reporting the loss in weight as moisture (A.O.A.C., 1975) or by distillation techniques (Fetzer, 1951). Pedlinger (1977), compared two analytical methods (A.O.A.C. and C.W. Brabender Semi-Automatic Moisture Tester) to determine percentage total moisture in cooked Longissimus

dorsi muscle, U.S. Choice or Good grade. She found similar results for both methods, and the values for the same sample never differed between methods by more than 1.4%. She also pointed out that the mean values for 48 samples differed between the two methods by 0.5% and by 0.9% for U.S. Choice and Good beef, respectively. In addition, the increasing emphasis placed on quality by the meat industry in recent years has challenged the development of rapid analytical procedures for simultaneous determination of moisture and fat (Wistreich et al., 1960; Davis et al., 1966).

Cooking properties. Cooking method: Many cooking procedures have been used for cooking meat patties in research work. Some of them are broiling, pan-broiling and grill frying. Modified Oven-Roasting, a dry heat method, is another cooking procedure which has been used in a series of research works. Hay et al. (1953), Cover and Hostetler (1960), and Bannister et al. (1971) have used this method in cooking beef and pork. Kendall et al. (1974) used it for cooking ground beef patties. Carlin and Harrison (1978) pointed out that Modified Oven-Roasting is used often for meat cuts suitable for broiling because cooking conditions are easier to control in modified oven roasting than in broiling. It is not necessary to turn the meat because heat is transmitted uniformally to all sides of the cut by air convection.

Rate of heat penetration: The rate at which the interior of a piece of meat will heat is influenced by a number of factors, including method of cooking, the cooking temperature, the shape and size of the sample being heated, the composition of the meat, the initial temperature of the meat and the changes induced in the meat by heat including protein denaturation, loss of water, connective tissue and melting of fat.

The rate at which heat is conducted in a piece of meat cooked by water, steam air or fat is different. Meat reaches a definite interior temperature much faster in water than in air of the same temperature (Lowe, 1955). Visser et al. (1960) pointed out that meat heats more rapidly in oil than in air, since heat conductivity of oil is about six times that of air.

In ground beef patties the internal composition, especially the amount of fat may influence heating rate. Irmiter et al. (1967) and Funk and Boyle (1972) reported that cooking rates of fabricated ground beef cylinders increased as the fat content increased.

Irmiter et al. (1967) found that in the early stages of cooking with an oven temperature of 121°C, meat with the least fat heated most rapidly, while in the latter stages of cooking, meat with the least fat heated more slowly. Laakkonen (1973) suggested that this idea may not be applicable to cooking intact muscle because grinding of meat causes severe changes in the structure of meat, and possibly more severe coagulation of proteins, and a larger amount of evaporation, followed by higher absorption of heat.

Funk and Boyle (1972) stated that the differences in rate of heat penetration in fabricated ground beef cylinders cooked at 121°C decreased as the oven temperature increased. They found that regardless of the composition, all cylinders cooked at 177°C required approximately the same cooking time, indicating that fat content had little influence on cooking time at this oven temperature. Lowe (1955) pointed out that a longer time is required for cooking when the initial meat temperature is low than when it is high.

Cooking losses: Total cooking losses from oven roasted meat are determined by measuring the weight change between raw and cooked meat, and are usually expressed as percentage of the raw weight (Paul, 1972). Those losses consist of drip that remains in the pan and volatile loss, which is the water that evaporates from the meat. The volatile loss is found by subtracting the weight of the cooked meat and drip from the weight of the raw meat. Cole et al. (1960) reported that in ground beef patties containing 45, 35, 25 or 15% fat, volatile losses decreased with an increase in fat content. Law et al. (1971) indicated that as the amount of fat content in ground beef increased, percentage of fat lost in cooking also increased.

Irmiter et al. (1967) found that cooking losses of frabicated ground beef cylinders with 10% or less fat were attributed to loss of moisture only. In meat containing more than 20% fat, loss of moisture by evaporation decreased significantly and fat loss in drip increased. When fat content was 30%, loss of moisture by evaporation appeared to be significantly retarded. Funk and Boyle (1972) reported that total and volatile losses in fabricated ground beef cylinders decreased as the fat content increased. Kendall et al. (1974) reported that ground beef patties containing 10 to 20% lipid had less cooking loss than those containing 25 to 30% lipid. Drake et al. (1975) found that in ground beef with and without textured soy protein and with 15, 20, 25 or 30% fat, fat loss upon cooking was dependent on the amount of fat in the patties and not on the soy protein level.

Moisture and fat content in cooked ground beef: Among the changes brought about by cooking, the loss of fat and fluids accounts for the

greater portion of the loss in weight during cooking. Paul (1972) suggested that fat comparisons should be made on the dry-weight basis. Irmiter et al. (1967) reported that percentage moisture in cooked ground beef cylinders decreased as ether extract in the raw product increased from 2 to 20%, but that no further decrease in moisture content was found in cylinders containing 30% fat. Law et al. (1971) reported that moisture (A.O.A.C. method) and fat content (chloroform-methanol-extract method) in a sample of cooked ground beef varied inversely. Funk and Boyle (1972) found that in fabricated ground beef cylinders with a lipid content of 30%, the percentage of ether extract decreased ($P < 0.01$) with cooking, whereas in samples with 3 or 15% lipid content, cooking did not affect significantly the percentage of ether extract. Kendall et al. (1974) reported that percentage total moisture (Brabender method) in cooked products increased as lipid content decreased (A.O.A.C. method). Drake et al. (1975) found that the initial amount of fat in raw ground beef patties (Hobart Fat Percent Indicator and the Soxhlet extraction methods) had no significant influence on the final moisture content (A.O.A.C. method) of the cooked product.

Sensory properties. Sensory methods have been used from the beginning of scientific investigation of meat palatability and are still popular today. They offer the advantage of a close simulation to "normal" eating conditions and thus can be used as reasonable criteria of general consumer acceptability (Szczeniak and Torgerson, 1965).

When meat is exposed to some degree of heat, changes occur; those are changes in tenderness, moisture content, color, size, shape and flavor. Crocker (1948) suggested that the meaty flavor developed by

cooking meat is brought about by breakdown of amino acids of the protein, particularly those of the fibers.

Wasserman (1967) reported that the role of fats in flavor is still undecided; however there are a number of workers who indicated that fat had little to do with the taste of cooked meat, but thought that it might modify the aroma somewhat. He also pointed out that fats may also be the source of some of the carbonyl compounds that react with amino acids in the browning reaction.

Law et al. (1965) found that a consumer taste panel preferred the flavor of 15% fat ground beef to that of ground beef containing 25 or 35% fat. Cole et al. (1960) reported that a trained laboratory taste panel did not detect significant differences in flavor in ground beef containing 45, 35, 25 or 15% fat. Kendall et al. (1974) reported that lean ground beef (9-12% lipid) rated lower in flavor than a higher-lipid product (30% fat). Cross et al. (1975) and Drake et al. (1975) found that various levels of fat had no effect on flavor of ground beef patties.

The most critical test applied to cooked beef by the consumer in assessing quality is tenderness. There is no universal agreement on the best way of conducting sensory texture measurements and different research groups use different methods (Szczeniak, 1968). Subjective scores for the eating quality of beef have been divided into juiciness and six components of tenderness by Cover et al. (1962a, b, c).

Cole et al. (1960) using a trained taste panel found that ground beef patties with 35% fat or above were significantly more tender than ground beef patties with 15 or 25% fat. Kendall et al. (1974) stated that their laboratory taste panel found that the leanest product (9-12%

lipid) tended to be more mealy in texture than products higher (20-30%) in lipid content.

Cross et al. (1976) reported that ground beef patties with 24 ± 2% fat from U.S. Prime, Choice and Good grade carcasses were rated tenderer than patties from U.S. Utility and Cutter grades. Huffman and Powell (1970), using the Allo Kramer shear and a trained taste panel, found that ground beef patties with 35% fat were more tender than those with 15 or 20% fat. Cross et al. (1978), using the Instron Universal Testing Machine with the single blade shear (SBS) and a trained laboratory panel, evaluated texture of ground beef patties with 24 ± 2% fat and found a high correlation (-0.92) for tenderness.

Kaiser et al. (1970) reported that panel members found no significant differences in tenderness among patties varying in fat content.

Juiciness as assessed by a taste panel, is largely determined by the amount of water present and by the ease with which it can be expressed from the meat as it is chewed. It also may be influenced by flavor, tenderness, and the amount of fat present (Paul, 1972).

Juiciness of cooked meat has been separated into two effects: (1) an initial impression of wetness produced by the rapid release of meat fluids during the first few chews, and (2) sustained juiciness, apparently the result of the slow release of serum and the stimulating effect of fat on saliva flow (Weir, 1960).

Law et al. (1965) and Kaiser et al. (1970) reported that taste panels did not detect significant differences in juiciness of ground beef patties varying in fat content. Cole et al. (1960) working with a trained taste panel found that a 35% fat sample was scored higher on juiciness than a 15, 25, or 45% fat sample. Kendall et al. (1974) reported that

the leanest ground beef product was less juicy than the higher-lipid product. Cross et al. (1975) reported that for ground beef patties juiciness ratings by a trained taste panel differed ($P < 0.05$) according to the fat content of the ground beef.

Juiciness is usually measured by a taste panel. In some experiments, the amount of fluid expressed under pressure correlated significantly with juiciness scores (Shaffer et al., 1973; Visser et al., 1960). Kendall et al. (1974) reported that as the lipid content of the ground beef products increased, press fluid contained less serum and more separable fat. Whereas, Gaddis et al. (1950) reported that in meat there was no relationship between percentage of press fluid and the score for quantity of juice, and that percentage of press fluid tended to decrease with an increase in fat content.

Also, juiciness of meat may be related to water-holding-capacity (WHC) and both are influenced by changes in pH. Bouton et al. (1975) reported that in raw meat of normal pH (5.4-5.8), moisture lost in cooking and the amount of juice extracted by high speed centrifugation of cooked meat were highly correlated ($r = 0.90$; $n = 200$) with juiciness assessed subjectively. Hamm and Deatherage (1960) reported that juiciness assessed by the measurement of cooking loss and centrifugally expressed juice, generally increased with increased pH.

Bouton et al. (1971) reported that the amount of juice centrifugally expressed from cooked mutton had a high positive correlation with organoleptic juiciness, and increased linearly with pH. Hamm (1959) suggested that grinding increases meat WHC by increasing the number of polar groups available for binding with the water molecules. Meat has a high WHC immediately after slaughter of the animal, but WHC decreases

very rapidly during the first 24 to 48 hr after slaughter. The formation of lactic acid, which in turn decreases pH, has some effect on decreased WHC.

Color and appearance, important factors in the appeal of fresh meat, are also considerations in the perceived palatability of cooked meat. The apparent degree of doneness in cooked ground beef can be determined by its internal color. Sprague and Grindley (1907) observed that rare roast beef may be a bright red color when its end-point temperature reaches 55-65°C. In medium done the outstanding characteristic is a more pink or rosy color at an end-point temperature range 65-70°C; whereas in well-done meat a uniform gray color is observed at an end-point temperature of 84-85°C.

Color stability

Background information. Color is a prime judgment of quality in meat products. The importance of meat color to consumer acceptability was demonstrated by Danner (1959) and Dunsing (1959), who showed that physical appearance of a retail cut was the most important factor used in meat selection. The consumer selects a meat cut primarily on leanness, and then on appearance and freshness, with the latter judgment based primarily on brightness of color (Rhodes et al., 1955; Seltzer, 1955).

The color of fresh meat is determined by the relative proportions of three meat pigments: purple reduced myoglobin (Mb), red oxymyoglobin (MbO_2), and brown metmyoglobin (MetMb). During storage of meat there is an accumulation of MetMb and a development of discoloration. This discoloration restricts attempts to market fresh beef by a centralized

prepackaging system (Zimmerman and Snyder, 1969). The chemistry of meat pigments responsible for fresh meat color has been reviewed extensively (Fox, 1966; Solberg, 1968, 1970; Govindarajan, 1973). In the presence of oxygen, Mb is converted to MbO_2 and to MetMb, the oxygenated (bright red) and the oxidized (brown) form, respectively.

Factors that affect color stability of meat: Govindarajan and Snyder (1973) pointed out that the color stability of meat is influenced by a series of factors such as: light, oxygen level, storage temperature, type of packaging, pH, and the presence of microorganisms.

Fresh meat color seems to be dependent on the type of light used in the display. Effects of fluorescent, incandescent and ultraviolet light upon fresh meat color have been reported by Ramsbotton et al. (1951) and Kraft and Ayres (1954). According to Ramsbotton et al. (1951), fluorescent light at an average of 60 to 200 ft candles resulted in no loss of color during a 3-day storage evaluation. However, Kraft and Ayres (1954) observed a steady change from bright red to dull red during the first 2 days exposure of fresh beef to 30 to 40 ft-candles of fluorescent light. Both Ramsbotton (1951) and Kraft and Ayres (1954) found that ultraviolet light was detrimental to fresh meat color. Setser et al. (1973) studied the oxidation of meat pigments at 254, 405, and 577 nm radiant energy in 0, 20, and 100% oxygen. They reported that there was a significant increase in MetMb content of the sample exposed to radiant energy over the controls.

Brody (1970) suggested that many of the reactions that influence the shelf life of fresh meat are temperature dependent. Snyder (1964) stated that decreased discoloration with decreased temperature was dependent on

contact of meat surfaces with air and decreased respiratory activity of the meat at the lower temperature.

The relative proportion of Mb, MbO_2 and MetMb in meat depends, to a large extent, on the partial pressure of oxygen in the muscle tissue. Snyder (1964) also demonstrated that increased partial pressure of oxygen in meat samples would provide extension of the oxymyoglobin pigment stability. Moreover, as oxygen is replaced by carbon dioxide, Gee and Brown (1978a, b) reported that both microbial shelf life and color shelf life were extended for refrigerated ground beef.

As pointed out earlier, another factor that affects the color stability of fresh meat is the presence of microorganisms. Microbial growth is one of the major factors that causes discoloration in fresh meats (Butler et al., 1953; Ockerman and Cahill, 1977; Solberg, 1968). Bala et al. (1977) reported that growth of Pseudomonas fragi had a significant ($P < 0.05$) effect on the color of aqueous beef extracted and stored at 1° ± 1°C. At the end of 10 days there was a 76% loss of MbO_2 in samples inoculated with P. fragi, and a 45% loss of MbO_2 in sterile control samples.

Cutaia and Ordal (1964) studied the effect of the amount of fat on the rate of MetMb formation and its conversion to reduced myoglobin in anaerobically packaged ground beef. They reported that as the amount of fat in the ground beef (0 to 40%) was increased, the rate of MetMb formation and conversion to Mb increased; and Rikert et al. (1957) found evidence that lean surfaces of samples in contact with a layer of fat were higher in redness after about one week of storage than the surface of the meat in contact with the packaging material. They demonstrated an

interaction between fat content and redness values in vacuum packaged ground meat.

Fox (1968) pointed out that postmortem glycolysis results in a build-up of lactic acid. The resulting drop in pH directly affects the reactivity of the heme pigment. That induces myoglobin oxidation because the oxidation of myoglobin is faster at lower pH values. Govindarajan and Snyder (1973) remarked that the changes in pH have a profound effect on the WHC of meat proteins, which in turn affects the gross morphology of the muscle. The color of meat is darker at a high pH (6.5) than at a low pH (5.3 to 5.5). The higher the pH, the more water that is bound to the protein of muscle, and the muscle shows a tightly packed compact structure and appears darker in color, because its surface scatters incident light to a small extent (dark cutting beef). On the other hand, a pH of 5.3 to 5.5 (normal meat pH) leads to a loss of water binding capacity of the protein of the muscle, resulting in a loose structure. Since the muscle is not compact, more incident light is scattered on the surface and the color is lighter than for dark cutting beef. In addition, Cutaia and Ordal (1964) found that in ground beef MbO_2 oxidizes faster at low pH than at high pH. Elliot (1967) reported that pH affects muscle color, the lower the pH the greater the Y value of the C.I.E. system.

Relation between color measurements and myoglobin pigments.

Although there is not a single method of color measurement completely free from criticism, reflectance measurement is the instrumental technique of choice for color evaluation, because it measures the color on

the surface of the meat as observed by the consumer, eliminating the need for extraction and it is nondestructive (Strange et al., 1974).

The percentage of reflectance in a meat sample indicates the amount of light reflected from the meat surface and depends on: (1) the concentration of meat pigments (Stewart et al., 1965b; Strange et al., 1974; Snyder and Armstrong, 1967; Snyder, 1965; Van den Oord and Wesdrop, 1971a), (2) the amount of fat present (Cutaia and Ordal, 1964; Rikert et al., 1957; Van den Oord and Wesdrop, 1971a; Elliot, 1967; Benedict et al., 1975), and (3) the amount of moisture at the surface of the meat and the oxidation or oxygenation state of the pigment (Cutaia and Ordal, 1964; Zimmerman and Snyder, 1969).

An effort to put reflectance data on a quantitative basis was use of the Kubelka-Munk function, which relates the ratio (K/S) of the absorption coefficient (K) and the scattering coefficient (S), to reflectivity (R_∞).

$$\frac{K}{S} = \frac{(1 - R_\infty)^2}{2R_\infty}$$

This equation has been used for determination of myoglobin pigments concentration (Table 1).

Relation between objective and subjective measurements for the determination of the myoglobin pigments. Meat color is a surface property. It can be measured by subjective evaluation or objectively by instruments. Although, subject evaluation has been used extensively, there is no uniformity in the color scale used. Attempts have been made to establish a correlation between objective and subjective measurements of color and the pigment composition of meat. In Table 2, there is a summary of some of the studies done in this area.

Table 1-Summary of the color measurements for myoglobin pigments reported in the literature.

Meat pigment	Color measurements	Ratio	Comments	References
MetMb	A507nm/A573nm	3.3	Extraction of myoglobin	Broumand et al. (1958)
	$\frac{K/S\ 507nm}{K/S\ 573nm}$		Intact muscle Ground beef	Dean and Ball (1960) Cutaia and Ordal (1964)
	$\frac{a}{b}$	0.4	Intact muscle Low value indicates high concentration of MetMb	Snyder (1964)
	R_A 571nm		Intact muscle Used R_A value adjusted to 1.0 at 525nm	Snyder (1965)
	$\frac{K/S\ 572nm}{K/S\ 525nm}$	100% MetMb = 0.56 0% MetMb = 1.40	Ground meat Low meat pH decreased K/S value	Stewart et al. (1965b)
	$\frac{K/S\ 571nm}{K/S\ 525nm}$	0.608	R_A = 1.0 at 525nm Suspension of myoglobin-dry milk mixture Linear relation between K/S value and meat pigment	Snyder and Armstrong (1967)
	$\frac{K/S\ 571nm}{K/S\ 525nm}$	0.59	Intact muscle	Zimmerman and Snyder (1969)
	$\frac{R_A\ 572nm}{R_A\ 525nm}\ \frac{K/S\ 572nm}{K/S\ 525nm}$		Intact muscle	Franke and Solberg (1971)

Table 1-(continued)

Meat pigment	Color measurements	Ratio	Comments	References
	R_A 632nm		Adjusted spectra to 750nm. No Mb present maximum value for MetMb	Franke and Solberg (1971)
MetMb	$\frac{K/S\ 507nm}{K/S\ 525nm}$	2.13	Intact muscle	Van den Oord and Wesdorp (1971a)
	$\frac{K/S\ 571nm}{K/S\ 525nm}$	0.55		
MetMb reducing activity (MRA)	$\frac{K/S\ 572nm}{K/S\ 525nm}$	1.34	Ground beef	Stewart et al. (1965a)
MetMb + MbO_2	%R(630nm - 580nm)		%R630nm predominant peak for MetMb %R580nm predominant peak for MbO_2 Linear relation No Mb present	Van den Oord and Wesdorp (1971a)
	%R(630nm - 580nm)		Ground beef (25% fat) %R 25 desirable red meat color	Benedict et al. (1975)
MbO_2	by differences $\%MbO_2 = 100 - (\%MetMb + \%Mb)$		Intact muscle	Dean and Ball (1960)
	$\frac{a}{b}$	2.1	Intact muscle	Snyder (1964)

Table 1-(continued)

Meat pigment	Color measurements	Ratio	Comments	References
MbO_2	$\frac{K/S\ 571nm}{K/S\ 525nm}$	1.327	R_A = 1.0 at 525nm Suspension of myoglobin-dry milk mixture	Snyder and Armstrong (1967)
	$\frac{K/S\ 474nm}{K/S\ 525nm}$	0.957	Linear relation between K/S value and meat pigment	
	$\frac{K/S\ 571nm}{K/S\ 525nm}$	1.36	Intact muscle	Zimmerman and Snyder (1969)
	$\frac{K/S\ 474nm}{K/S\ 525nm}$	0.88		
	$\frac{K/S\ 571nm}{K/S\ 525nm}$	1.49	Intact muscle	Van den Oord and Wesdorp (1971a)
	$\frac{K/S\ 474nm}{K/S\ 525nm}$	0.91		
Mb	$\frac{A\ 473nm}{A\ 597nm}$	2.55	Extraction of myoglobin	Broumand et al. (1958)
	$\frac{K/S\ 473nm}{K/S\ 597nm}$		Intact muscle Ground beef	Dean and Ball (1960) Cutaia and Ordal (1964)
	$\frac{a}{b}$	1.8	Intact muscle	Snyder (1964)
	$\frac{R_A\ 474nm}{R_A\ 525nm}$		Intact muscle R_A adjusted to 1.0 at 525nm	Snyder (1965)

Table 1-(concluded)

Meat pigment	Color measurements	Ratio	Comments	References
Mb	$\frac{K/S\ 473nm}{K/S\ 525nm}$	0.543	R_A = 1.0 at 525nm Suspension of myoglobin dry milk mixture Linear relation between K/S value and meat pigment	Snyder and Armstrong (1967)
	$\frac{K/S\ 473nm}{K/S\ 525nm}$	0.53	Intact muscle	Zimmerman and Snyder (1969)
Myoglobin oxidate or reductive changes	%R(623nm - 614nm)		Intact muscle not affected by surface dry or inclusion of fat	Eagerman et al. (1978)
MetMb + MbO_2 + Mb	K/S 525nm		Isobestic point K/S 525nm produce a linear relation to total pigment	Stewart et al. (1965a)

%R = percentage of reflectance

A = absorbance

R_A = reflectance on the absorbance scale

$\frac{a}{b}$ = Gardner ratio

K/S = ratio of absorption to scattering of light calculated from percentage reflectance

Table 2-Summary of the objective and subjective measurements for the determination of myoglobin pigments reported in the literature.

Color measurements	Correlation coefficient (r)	Visual parameters	Comments	References
%R 485nm	0.819	Panel score 0 to 7	Beef muscle	Ockerman and
%R 505nm	0.822	0 = dark cutter (black)	%R 685nm was	Cahill (1969)
%R 565nm	0.793	7 = very light	the best method	
%R 685nm	0.873		of estimating visual color	
C.I.E. X	0.868		for beef	
Y	0.844			
Z	0.769			
Chromaticity coordinates				
Lx	0.371			
Ly	0.572			
$A_{580} - A_{630}$	0.94	Panel score 1 to 10	BF and PM muscle	Van den Oord
		1 = extremely bad	Panel score less	and Wesdorp
		10 = extremely good	than 5.5 consid-	(1971b)
			ered unacceptable	
%R 625nm	-0.77**	Panel score 1 to 9	Spectronic 20.	Jeremiah
%R 655nm	-0.76**	1 = very pale pink	Beef loins	et al. (1972)
		9 = very dark	** ($P < 0.01$)	

Table 2-(continued)

Color measurements	Correlation coefficient (r)	Visual parameters	Comments	References
C.I.E. X	-0.81**			Jeremiah et al. (1972)
Y	-0.80**			
Z	0.08			
Gardner Rd	-0.79**			
a	-0.67**			
b	-0.78**			
%R 630nm - %R 580nm	0.862	Panel hedonic scale 0 to 50 0 = totally unacceptable 30 = marginally acceptable 50 = extremely acceptable	ST muscle "a" value was the most accurate replacement for the hedonic	Strange et al. (1974)
Gardner Rd				
a	0.910			
b				
%R 630nm	0.48	Beef Color Circular	LD beef muscle 1 day frozen display	Kropf et al. (1976)
%R 635nm	0.48			
%R 650nm	0.48			
Hunter L	0.133	Panel score 40 to 45 excellent meat color 30 to 39 good to very good meat color 20 to 29 fair to good meat color 10 to 19 passable meat color Below 10 unacceptable meat color	ST muscle	Eagerman et al. (1977)
a	0.715			
b	0.406			
C.I.E. X	0.151			
Y	0.040			
Z	0.189			

Table 2-(concluded)

Color measurements	Correlation coefficient (r)	Visual parameters	Comments	References
%R 632nm - %R 614nm	0.618		SM muscle	Eagerman et al. (1977, 1978)
%R 630nm - %R 580nm		Beef Color Circular	Beef muscle recommended used	Harrison et al. (1979)

%R = percentage reflectance
A = absorbance
X = (amber)
Y = (greenness)
Z = (blueness)
Rd = (reflectance)
a = (redness or greenness)
b = (yellowness or blueness)
BF = biceps femoris muscle
PM = psoas major muscle
ST = semitendinosus muscle
LD = longissimus dorsi muscle
SM = semimembranosus muscle
Beef color, undated

Eagerman et al. (1977) stated that when people evaluate fresh meat for color acceptability or desirability, they tend to think in terms of how the viewed samples differ from the mental impression of "ideal meat color" and then rate the sample accordingly. Those authors concluded that deviations from the "ideal" may create a problem when trying to develop an instrumental procedure that will correlate well with the visual parameters.

MATERIALS AND METHODS

Preparation of the products

Product for this experiment was available from a project in the Department of Animal Sciences and Industry at Kansas State University. Cattle of U.S. Choice and U.S. Good grades with weights between 410 and 500 kg were slaughtered, and at one hour after bleeding the right side of each carcass was electrically stimulated. For that procedure, a probe was inserted at the achilles tendon end of the semimembranosus muscle and another probe was inserted in the neck over the humerus. Electricity (ca 600 volts, 5 amperes) was applied to the right side of the carcass for two min at a frequency of 60 cycles per second. The left side of the carcass was the non-stimulated control and was placed in the cooler (5° ± 2°C) for 48 hr.

At two hours postmortem beef flanks were removed from the electrically stimulated side of three carcasses and divided into fat and lean, which were placed in vacuum bags. A partial vacuum was pulled on the bags, and the product was stored overnight at 3°C, then blast frozen at -26°C. Flanks from the non-stimulated, chilled sides of three carcasses

were handled the same as those from electrically stimulated, hot boned sides.

Beef flank products were removed from the freezer, thawed in the vacuum bags 48 hr at 3°C; then, six ground beef products containing approximately 10, 15 or 20% fat were formulated. The lean portion of the flanks was ground using a plate with holes 1.3 cm in diameter, followed by a second grinding through a plate having holes 0.3 cm in diameter. The fat was ground once through the plate with holes 1.3 cm in diameter.

Samples of ground muscle (56.7 ± 0.01 g) were analyzed for fat content, using the method of thermal fat analysis developed by the Hobart Manufacturing Co. (Patent No. 3183710, Troy, Ohio). The proportions of ground lean and fat trim required for ground beef containing 10, 15 or 20% fat were determined by the Pearson square (adapted from Pearson, 1912, Appendix, p. 101).

Six ground beef products (electrically stimulated and hot boned, ES, 10, 15 or 20% fat and conventionally chilled, CC, 10, 15 or 20% fat) were prepared and each product was divided into 9, 600-g portions and 9, 60-g portions. Each 600-g portion was wrapped in aluminum foil (0.0015 gauge). One portion was used to evaluate the fresh products for cooking properties, sensory characteristics and objective measurements. The other eight portions were frozen at -26°C, and were stored (5 to 30 days, -30°C) until they were examined for the same properties as those listed above for the fresh products. The 60-g portions were packaged in Whirl-pak freezer bags; one 60-g portion was used to evaluate color stability, pH and microbial counts of each fresh raw product; eight portions were frozen at -26°C and were stored at -30°C in the dark (2 to 4 1/2 months)

until they were evaluated in the same manner as the 60-g portions of each fresh product.

Experimental design and analysis of data

The design for the cooked products was a randomized complete block with eight replications (Table 7, Appendix, p. 102). Each replication represented one block. The analysis of variance (AOV) for the data for cooked products except data for total moisture (A.O.A.C.) and ether extract was:

Source of Variation			DF
Replications			7
Treatments			5
ES vs CC	(A)	(1)	
Fat %	(B)	(2)	
A x B		(2)	
Error			35
Total			47

The AOV for total moisture (A.O.A.C.) and ether extract in cooked products was:

Source of Variation			DF
Replications			3
Treatments			5
ES vs CC	(A)	(1)	
Fat %	(B)	(2)	
A x B		(2)	
Error			15
Total			23

The design for color stability, pH and microbial counts for raw products was a completely randomized design (Table 8, Appendix, p. 103). The AOV was:

Source of Variation			DF
Treatments			5
ES vs CC	(A)	(1)	
Fat %	(B)	(2)	
A x B		(2)	
Error			42
Total			47

At each evaluation period, one 600-g portion of three frozen products, selected according to the experimental design was defrosted 4 hours at 22° to 25°C and 18 hr at 4°C.

Three 180-g patties, approximately 2.5 x 7.6 x 8.2 cm were molded from each ground beef product; a centigrade thermometer was placed in the geometric center of each pattie. The patties were placed side by side on a wire rack 10 cm in height, set in a shallow pan and cooked in a rotary hearth electric oven maintained at 177°C for 35 min. Fresh, unfrozen products were cooked by the same method as described for the frozen products.

Rate of heat penetration, cooking losses

The rate heat penetrated the patties made from the frozen products was observed by recording the time (in min) required for the internal temperature of the center pattie to increase 10°C between 10° ± 2°C and 50°C and for every 5°C increase between 50°C and the internal end-point temperature after 35 min of cooking. At the end of the cooking period, the temperature reached in the patties was recorded, and percentages of total, volatile and drip cooking losses, based on the weight of the three raw patties, were calculated. For objective measurements and sensory evaluation the crust of each pattie was removed.

Sensory evaluation

Cores (2.5 cm diameter, 2.5 cm thick) were cut from two cooked patties (Figure 12, Appendix, p. 105) of each level of fat and placed in the top half of a one pint enamel double boiler set over hot water (approximately 65°C) in the bottom part. The entire system was held at low heat (35°C ± 1°C) on an electric hot tray until the meat was

evaluated by all panel members (within 15 min after preparation of the samples).

Flavor, juiciness, texture, tenderness and apparent degree of doneness were evaluated by a 6- to 7-member laboratory panel. Instructions for evaluation were given in writing and discussed with panel members (Form I, Appendix, p. 106) in preliminary work. Panel members randomly selected one core from each of the double boilers and evaluated it using a 5 to 1 scale. Flavor was scored for intensity (5 = intense beef flavor to 1 = no beef flavor); juiciness also was scored on an intensity scale (5 = juicy to 1 = dry). Texture and tenderness were scored for type (5 = mealy or tender to 1 = chewy or tough). The third pattie was sliced through the center and one-half of it was covered with a transparent household plastic wrap, and placed under a MacBeth Skylight to be rated rare, 1; medium-done, 3; or well-done, 5 (Form II, Appendix, p. 107).

Ether extract, total moisture and press fluid

Percentages of ether extract and total moisture in both raw and cooked ground beef products were measured according to the AOAC method (AOAC, 1975) by the Analytical Services Laboratory of the Department of Animal Sciences and Industry at Kansas State University. Also, percentage total moisture in cooked ground beef was determined by drying duplicate 10-g samples in a C.W. Brabender Semi-Automatic Rapid Moisture Tester for 60 min at 121°C.

Press fluid from each product was measured on duplicate 25-g samples of cooked ground beef packed in a cheesecloth lined steel cylinder of a Carver Laboratory Press. The sample was divided roughly

into thirds, and packed in the cylinder by alternating, the meat with four circles (5.5 cm in diameter) of Whatman No. 1 filter paper. A leather disc was placed on top of the last circle of filter paper and the steel plunger was inserted into the cylinder. The packed cylinder was pressed following a standardized 15-min time-pressure schedule (Appendix, p. 108), with maximum pressure of 4,000 psig. The expressed fluid was poured into centrifuge tubes graduated in 0.1 of a ml, capped with aluminum foil and placed in a refrigerator until the following day when the volumes of total press fluid, serum and fat were read.

Color stability, pH and microbial counts

The 60-g portions from each frozen product were thawed four hours at 4°C. One 10-g sample from each product was used for pH determination within one hour after thawing. Another 10-g sample from each product was used for microbial counts within two hours after thawing. One 20-g sample from each product was placed in a metal sample holder, covered with an air permeable film, packaged in Whirl-pak bags, and stored in a refrigerator at 4°C for one hour in the dark, then exposed to radiant energy after which spectrophotometric scans were made. Fresh samples of ground beef (ES and CC with 10, 15 or 20% fat) were examined for color stability, pH and microbial counts following the same procedures as those used for the frozen products.

Exposure and spectral reflectance. The 20-g samples from products of each level of fat were exposed to radiant energy for four hours with spectrophotometric scans made every 30 min. Exposed samples were subjected to radiant energy at 577 nm and a temperature of 4° ± 1°C for four hours in an atmosphere of 20% oxygen. The cooling system consisted of

forcing compressed air (20% oxygen) through a moisture condensing trap into a copper coil suspended in liquid nitrogen, and then into the sample chamber where exposure to radiant energy occurred (Fig. 1).

The source of radiant energy was a 500-watt medium pressure mercury lamp fitted with a standard mercury line interference filter (577 nm) for selective absorption of unwanted spectral components. Intensity of radiant energy at 577 nm was 0.8×10^{-3} w/cm^2 as measured by a IL 500 radiometer (International Light, Newburyport, MA) with SE E010 #127 detector.

All samples were exposed and measured spectrophotometrically at the same surface location. Reflectance values were recorded for each experimental sample at 30 min intervals with a HunterLab Spectrophotometer Model D54P-5.

A scan of each sample was made across the spectrum from 400 to 710 nm. Percentage reflectance at 474, 525, 571, 580, 614, and 630 nm; K/S values for reflectance at 474, 525, and 571 nm and HunterLab L, a, and b values were determined. A white standard with calculated values of L (94.2), a (-1.0) and b (+1.3) was used to calibrate the instrument. Also, the HunterLab L, a, b values were measured for 25-g samples of the cooked ground beef ES and CC containing each level of fat.

Raw samples were scored subjectively for color on a 6-point scale, 1 being designated very bright red and 6 grey-brown. Color photographs in "Lamb Color" (Lamb Committee, National Live Stock & Meat Board and American Lamb Council, undated) were used as color references.

pH and microbial counts. Duplicate pH readings were made on slurries of 10 g ground beef (raw or cooked ES and CC containing each

Fig. 1 Light exposure and cooling system

A. Compressed air

B. Sample holder

C. Cooling system

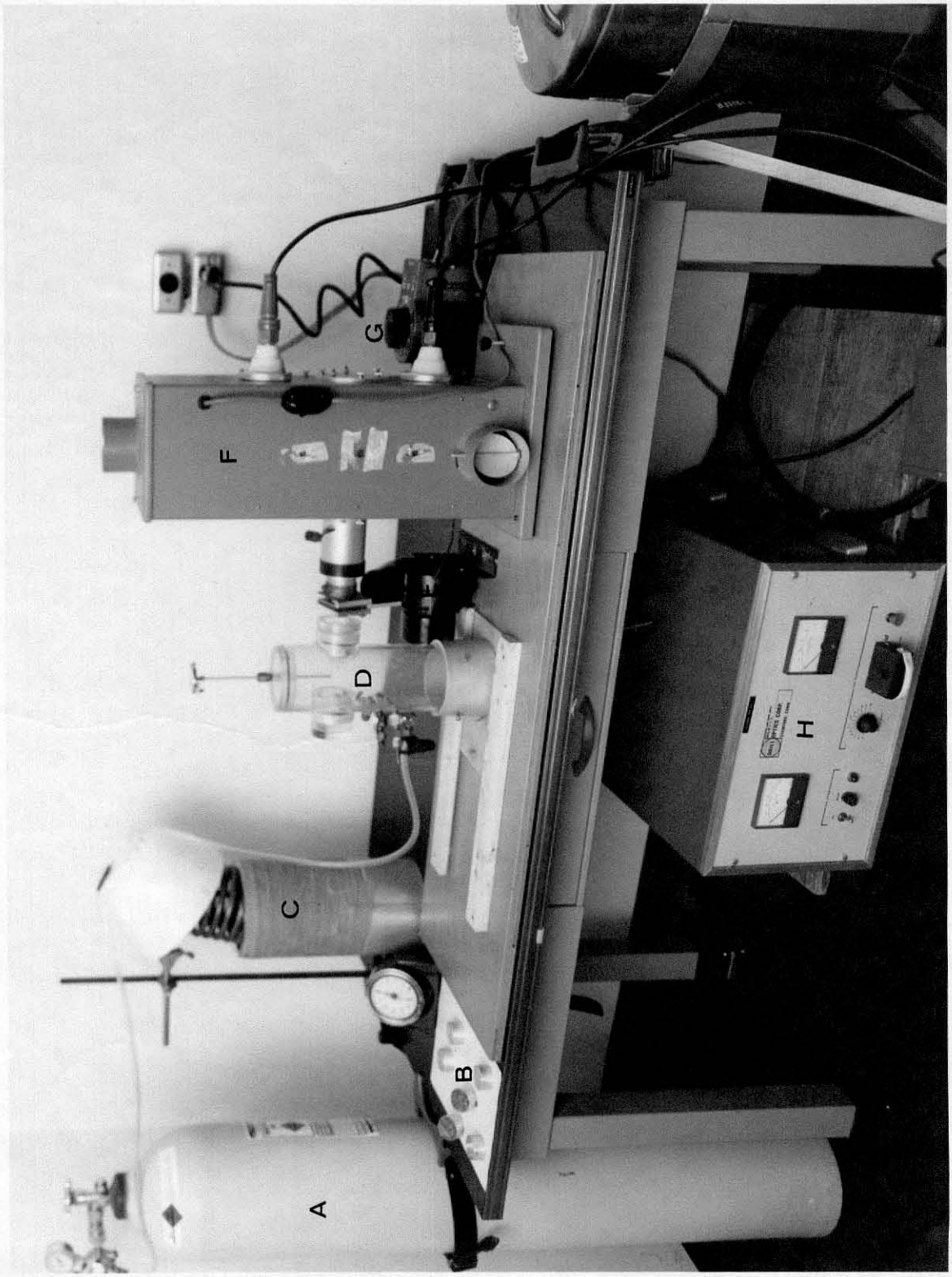
D. Sample chamber

E. Blower to cool filter

F. Housing for mercury lamb

G. Variable power regulator

H. Power supply


A
B
C
D
F
G
H

level of fat) and 100 ml distilled water according to the method of Rogers et al. (1967). For microbial counts, a 10-g sample of raw ground beef from ES and CC of each level of fat was weighted into a sterile 1 liter blender. Following addition of 90 ml of sterile phosphate buffer water, the sample was blended at high speed for 3 min. Serial dilutions from 10^{-3} through 10^{-6} were prepared.

The experimental conditions for microbial counts were selected after preliminary work, which showed that at 32°, 25°, and 5°C incubation temperatures the counts obtained were viable. For aerobic plate count (APC), duplicate plates for dilutions 10^{-3} through 10^{-6} were prepared and poured in accordance with the FDA Bacteriological Analytical Manual for Foods (BAM). Plates were incubated at 32°C for 72 ± 2 hr. For psychrotrophic plate count (PPC), duplicate plates for dilutions 10^{-3} through 10^{-6} were prepared in the same way as those for the APC procedure. PPC plates were incubated at 25°C ± 1°C for 72 ± 2 hr, and at 5°C for 10 days. The APC and PPC plates with between 30 and 300 colonies were counted using a Quebec Colony Counter, Model 3327 and according to a standard procedure for counting colonies (Marth, 1978).

RESULTS AND DISCUSSION

It should be noted that while the intent of this study was to compare three fat levels, namely 10, 15 and 20% fat, the analytical values for the ES groups were: 8.60, 15.83, and 25.45; and for the CC group: 6.67, 12.95, and 22.58. The data for cooking and sensory properties (Table 9, Appendix), and color stability (Tables 23, 24, 25, 26, 27, and 28, Appendix) of the fresh products were not analyzed statistically.

End point internal temperature and rate of heat penetration

Generally, there was little difference in mean end point internal temperature for any of the sample groups after 35 min cooking at 177°C (Table 3). Those results are in agreement with the findings of Funk and Boyle (1972) who stated that regardless of the composition, all ground beef cylinders cooked at 177°C required approximately the same cooking time, indicating that fat content had little influence on cooking time at that oven temperature.

Analysis of variance (Table 11, Appendix) indicated no significant differences between ES and CC groups or among the different fat levels for initial raw meat temperature. In Figure 2 the rate of heat penetration for the CC group can be observed. The time required to raise the internal temperature from the initial temperature to 20°C was a little greater for the 20% fat samples than for the 10 or 15% fat samples. That pattern was consistent up to 60°C; between 60° and 70°C there were no differences attributable to fat levels. Figure 2 shows rate of heat penetration for the ES group. Contrary to what occurred with the CC group, for the ES samples the time required to raise the internal temperature from the initial temperature to 20°C was a little longer for 10 and 15% fat samples than for the 20% fat samples. That pattern was consistent up to 55°C. From 55° to 70°C, the 20% fat samples cooked faster than the 10 or 15% fat samples. Details for both ES and CC groups with the three levels of fat can be observed in Figure 3. For both ES and CC groups at 177°C oven temperature, heat penetrated the patties at a fairly constant rate. In general, there were no significant differences between ES and CC or among the fat levels for the time required to reach 70°C.

Table 3-Mean values, standard errors and LSDs for objective and subjective measurements of thawed ground beef

Measurements		Treatments[a] ES10	ES15	ES20	CC10	CC15	CC20	LSD[b]
End-point internal temp., °C	Mean	70.80e	70.90e	72.60f	70.90e	71.90ef	71.90ef	1.26
	S.E.	0.44	0.44	0.44	0.44	0.44	0.44	
Cooking losses, %								
Total	Mean	25.90e	29.90f	36.10	25.90e	28.30f	33.30	1.69
	S.E.	0.59	0.59	0.59	0.59	0.59	0.59	
Volatile	Mean	22.50e	22.40e	20.70f	22.20ef	21.60ef	18.90	1.58
	S.E.	0.55	0.55	0.55	0.55	0.55	0.55	
Drip	Mean	3.20e	6.90	14.70f	3.50e	5.20	13.30f	1.54
	S.E.	0.54	0.54	0.54	0.54	0.54	0.54	
Total moisture, %								
A.O.A.C., raw[h]	Mean	71.20e	66.24f	58.38g	70.25e	66.18f	58.49g	3.88
	S.E.	1.29	1.29	1.29	1.29	1.29	1.29	
A.O.A.C., cooked[h]	Mean	67.29e	60.61f	55.39	67.36e	63.17ef	60.13f	4.36
	S.E.	1.45	1.45	1.45	1.45	1.45	1.45	
Brabender, cooked	Mean	63.11	56.21	53.06	64.18	57.96	54.20	1.06
	S.E.	0.37	0.37	0.37	0.37	0.37	0.37	
Ether extract, %								
A.O.A.C., raw[h]	Mean	8.60e	15.83f	25.45g	6.67e	12.95f	22.58g	4.18
	S.E.	1.39	1.39	1.39	1.39	1.39	1.39	
A.O.A.C., cooked[h]	Mean	8.96e	15.70f	22.11	7.44e	13.75f	17.32f	3.73
	S.E.	1.24	1.24	1.24	1.24	1.24	1.24	

Table 3-(continued)

Measurements		Treatments[a] ES10	ES15	ES20	CC10	CC15	CC20	LSD[b]
pH, cooked	Mean	5.96f	5.98f	5.99ef	6.07e	5.99ef	6.04ef	0.09
	S.E.	0.03	0.03	0.03	0.03	0.03	0.03	
Press fluid, ml/25g								
Total	Mean	8.50ef	8.70e	8.10f	8.70e	8.20ef	8.00f	0.54
	S.E.	0.19	0.19	0.19	0.19	0.19	0.19	
Serum	Mean	7.40e	5.70f	4.90g	7.50e	6.10f	4.70g	0.75
	S.E.	0.26	0.26	0.26	0.26	0.26	0.26	
Fat	Mean	1.10e	2.90f	3.00f	1.20e	2.10	3.30f	0.55
	S.E.	0.19	0.19	0.19	0.19	0.19	0.19	
Sensory scores[c], 5-1								
Flavor	Mean	3.20efg	3.40fg	3.50g	2.90e	3.10ef	3.10ef	0.32
	S.E.	0.11	0.11	0.11	0.11	0.11	0.11	
Juiciness, Initial	Mean	2.80e	3.80g	3.70g	2.90e	3.20ef	3.50fg	0.40
	S.E.	0.14	0.14	0.14	0.14	0.14	0.14	
Sustained	Mean	2.80e	3.50f	3.60f	3.00e	2.90e	3.40f	0.32
	S.E.	0.11	0.11	0.11	0.11	0.11	0.11	
Texture	Mean	3.00e	3.20e	3.10e	3.00e	3.10e	3.20e	---
	S.E.	0.10	0.10	0.10	0.10	0.10	0.10	
Tenderness	Mean	3.40ef	3.60fg	3.70g	3.30e	3.30e	3.60fg	0.26
	S.E.	0.09	0.09	0.09	0.09	0.09	0.09	

Table 3-(concluded)

Measurements		Treatments[a]						LSD[b]
		ES10	ES15	ES20	CC10	CC15	CC20	
Sensory scores[c], 5-1								
Apparent degree of doneness[d]	Mean	3.40e	3.70ef	4.20g	3.60e	4.10g	4.00fg	0.32
	S.E.	0.11	0.11	0.11	0.11	0.11	0.11	
Color difference HunterLab Spectrophotometer (cooked)								
L (Lightness)	Mean	48.56f	47.95ef	47.08e	48.22ef	47.89ef	47.56ef	1.20
	S.E.	0.41	0.41	0.41	0.41	0.41	0.41	
a+ (redness)	Mean	4.87e	4.31ef	3.63g	4.66e	3.96fg	3.94fg	0.59
	S.E.	0.21	0.21	0.21	0.21	0.21	0.21	
b+ (yellowness)	Mean	8.85e	8.74e	8.45e	8.90e	8.59e	8.60e	---
	S.E.	0.19	0.19	0.19	0.19	0.19	0.19	

[a]Treatments: CC10, 15, 20 = Conventionally chilled 10, 15, 20% fat; ES10, 15, 20 = Electrically stimulated 10, 15, 20% fat.

[b]Least significant difference at 5% level of probability; means having the same letter (e-g) are not significantly different.

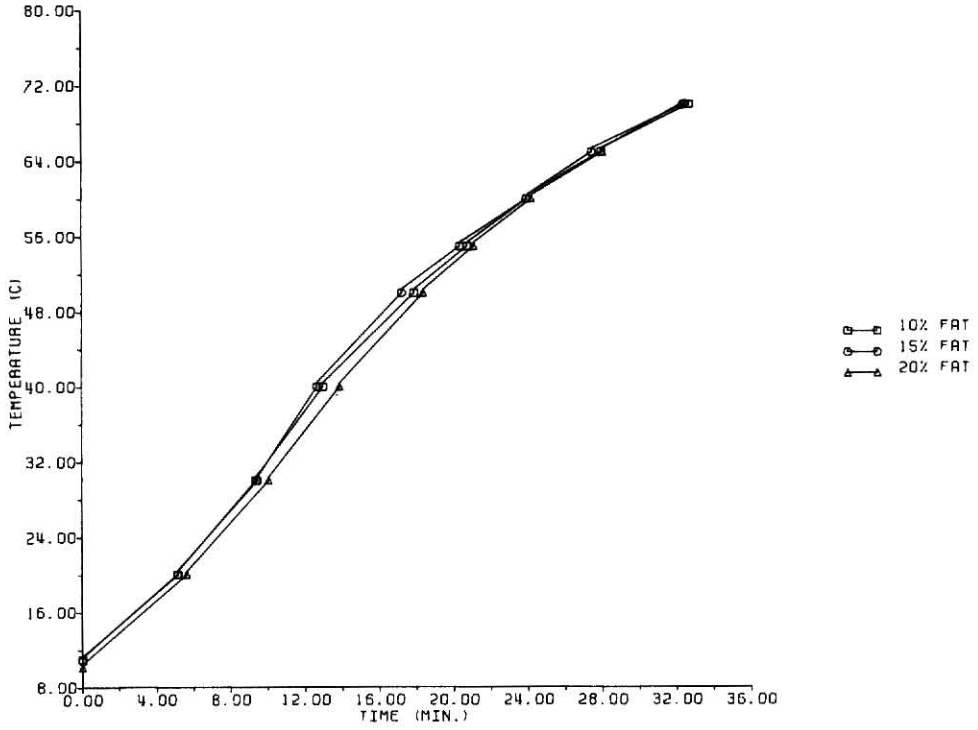
[c]Range: 5 = intense beef flavor, juicy, mealy or tender; 1 = no beef flavor, dry, chewy or tough.

[d]5 = well done; 3 = medium done; 1 = rare.

[h]n = 4; all other measurements n = 8.

Fig. 2. Rate of heat penetration from initial temperature to 70°C for Electrically Stimulated (ES) and Conventionally Chilled (CC) ground beef with three fat levels cooked by dry heat at 177°C.

RATE OF HEAT PENETRATION
CONVENTIONAL CHILLED



RATE OF HEAT PENETRATION
ELECTRICAL STIMULATED

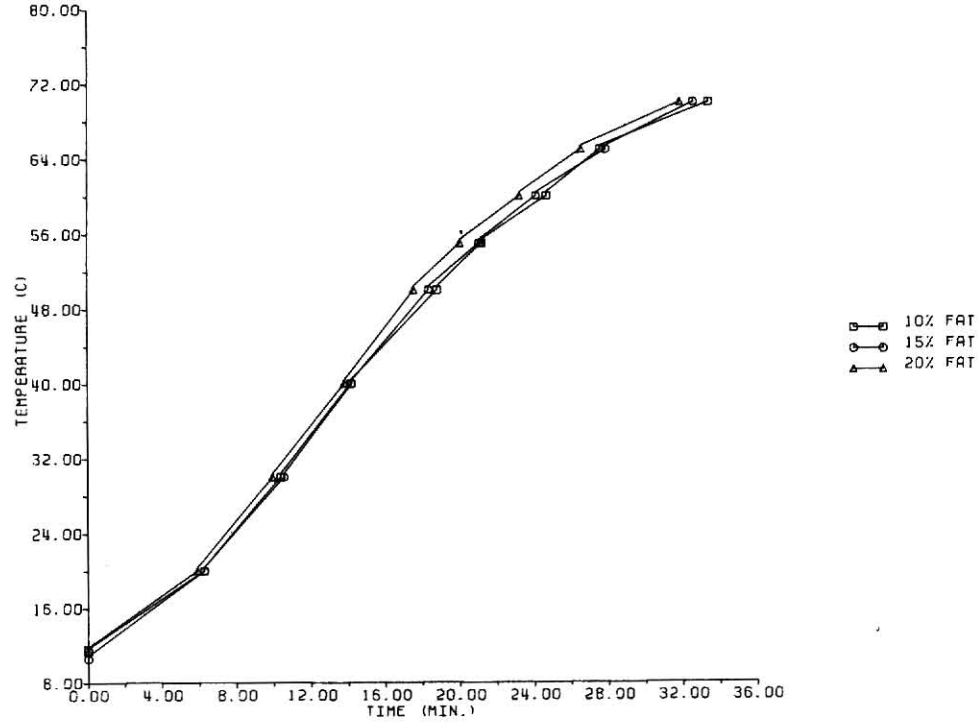
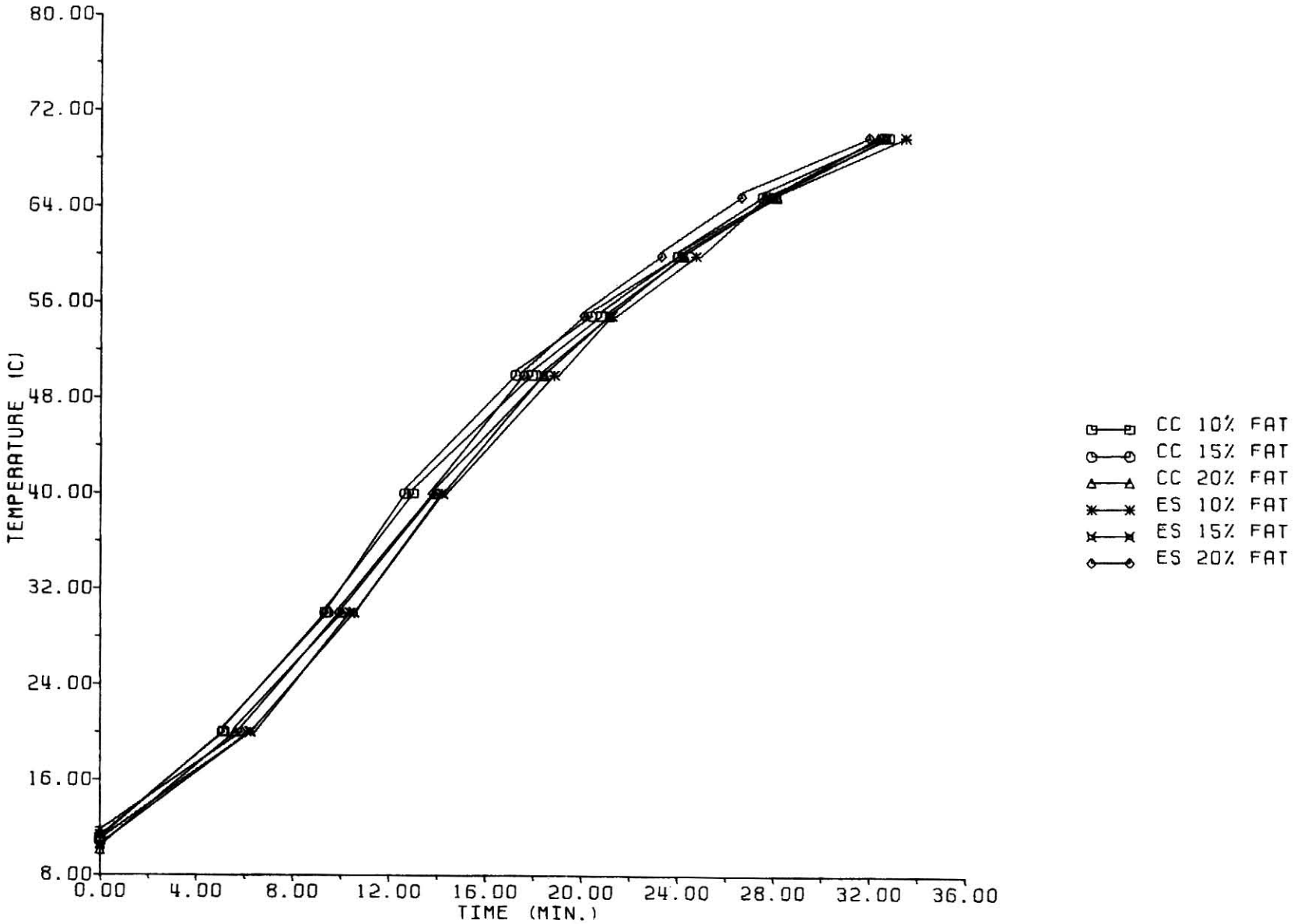


Fig. 3 Rate of heat penetration from initial temperature to 70°C for six ground beef products with three fat levels cooked by dry heat at 177°C.


80.00
72.00
64.00
56.00
48.00
40.00
32.00
24.00
16.00
8.00
TEMPERATURE (C)
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
TIME (MIN.)
CC 10% FAT
CC 15% FAT
CC 20% FAT
ES 10% FAT
ES 15% FAT
ES 20% FAT

Cooking losses

Mean values for percentage total cooking losses in all sample groups increased ($P < 0.05$) as percentage of fat in the ground beef patties increased (Table 3). Similarly, Kendall et al. (1974) reported that ground beef patties containing 10 to 20% lipid had less cooking losses than those containing 25 to 30% lipid. In general, mean values for percentage of volatile cooking losses indicated that as percentage of fat in each sample group increase, volatile losses decreased ($P < 0.05$) in all samples for both ES and CC groups (Table 3). Also, Cole et al. (1960), Irmiter et al. (1967), and Funk and Boyle (1972) reported that volatile losses decreased with an increase in fat content. Mean values for percentage of drip cooking losses in all sample groups increased ($P < 0.05$) as percentage of fat in the ground beef patties increased (Table 3). Law et al. (1971) reported that as the amount of fat content in ground beef increased, percentage of fat lost in cooking also increased. The ES group samples showed higher mean values for percentage of total, volatile, and drip losses than the CC group samples. The analysis of variance for total, volatile, and drip cooking losses (Table 20, Appendix) showed that there were significant differences between ES and CC groups for the cooking losses. In general, those differences ($P < 0.05$) in cooking losses could be attributable to the 20% fat samples (Table 3).

Total moisture and ether extract

As expected, percentage of total moisture in raw and cooked samples decreased as percentage of fat increased as determined by both A.O.A.C. and Brabender methods (Table 3). For raw meat (A.O.A.C.), total moisture for each fat level differed ($P < 0.05$) from that for every other fat

level. Also, percentage of total moisture for the cooked ground beef patties (A.O.A.C. and Brabender methods) decreased as percentage of fat (ether extract, cooked) increased (Table 3), but the decrease was not always significant with each increase in fat level. Similarly, Law et al. (1971) reported that moisture (A.O.A.C. method) and fat content (chloroform-methanol-extract) in cooked ground beef varied inversely. Irmiter et al. (1967) and Kendall et al. (1974) reported that percentage moisture in cooked ground beef samples decreased as lipid content increased. In this study, there were differences ($P < 0.05$) in total moisture between ES and CC cooked ground beef patties with both A.O.A.C. and Brabender methods. The CC group showed slightly higher mean values than the ES group (Table 3).

Mean values for percentage of ether extract in raw ground beef patties are shown in Table 3. Analysis of variance showed differences ($P < 0.01$) among the fat levels (Table 20, Appendix); the mean values (Table 3) for the ES group were higher than those for the CC group. Raw samples in the ES group contained more ether extract and total moisture and had higher volatile cooking losses than the raw samples in the CC group.

An increase in the mean values for percentage of ether extract for raw to cooked was observed. This is in agreement with the results of Woolsey and Paul (1969) who reported that both petroleum ether (non-polar solvent) and chloroform-methanol (polar solvent) extracted significantly more crude fat from cooked than from raw, lean, intact semitendinosus muscle, even when results were calculated on a dry weight basis. Moreover, differences in the amount of fat extracted by the two solvents were not significant. They hypothesized that heating caused

denaturation of protein and subsequent release of lipids previously complexed with protein so that lipid was more accessible to both polar and nonpolar solvent extraction. They also suggested that the slow increase in temperature at the beginning of the cooking process may have activated enzymes, which in turn released bound fat.

pH and press fluid

Mean values for pH of the cooked ground beef patties were lower ($P < 0.05$) for the ES group than for the CC group. However, there were no significant differences in pH values among the fat levels within a group, i.e., fat content did not affect the mean pH value of the cooked ground beef patties (Table 3).

In general, total and serum press fluid for both ES and CC groups decreased as the percentage of fat in the ground beef samples increased; whereas, as the percentage of fat in the ground beef samples increased there was more separable fat in the press fluid (Table 3). Also, Kendall et al. (1974) and Gaddis et al. (1950) found that as the lipid content of the ground beef samples increased, press fluid contained less serum and more separable fat. It can be observed that the mean serum press fluid values for the CC group were higher than for the ES group. Cooked samples in the CC group contained more serum press fluid and total moisture, and had lower volatile cooking losses than the cooked samples in the ES group. There appears to be some relationship between the amount of serum extracted by press fluid and pH. The CC group showed a higher mean pH value and higher mean serum press fluid value than the ES group, which is in agreement with the findings of Hamm (1959) and Cross et al. (1979) who suggested that the formation of lactic acid, which in turn

decreased pH, has some effect in decreasing WHC, which can be related to cooking losses and centrifugally expressed juice.

Sensory evaluation

There were no significant differences in flavor scores attributable to fat levels within a group. The mean values increased slightly as fat content increased (Table 3). This is in agreement with the findings of Kendall et al. (1974) who reported that the lean ground beef (9 to 12% lipid) rated lower in flavor than a higher lipid product (30% fat). There were differences ($P < 0.05$) between ES and CC groups. The ES group showed higher mean values (more intense beef flavor) than the CC group.

In general, initial and sustained juiciness scores increased slightly as the level of fat increased (Table 3). Similarly, Cole et al. (1960), Kendall et al. (1974) and Cross et al. (1975) reported that for ground beef patties juiciness ratings were related to the fat content of the ground beef patties. Apparently, fat content affects juiciness scores; the higher the fat content, the juicier the meat appeared to the panel. When data for all six treatment combinations were analyzed, juiciness scores differed ($P < 0.01$, Table 20, Appendix) between ES and CC groups with the ES samples being juicier than the CC samples (Table 3).

Texture of the cooked ground beef samples was not affected significantly by treatment combination or by fat level. There were no differences in tenderness scores between ES and CC groups; however, the trained laboratory taste panel scored the ground beef patties with the higher fat content as more tender ($P < 0.05$) (Table 3). That was similar to the findings of Cole et al. (1960) and Huffman and Powell (1970), who

reported that ground beef patties with 35% fat were significantly more tender than ground beef patties with 15 to 20% fat.

Apparent degree of deoneness scores were not influenced by the treatment combination (ES or CC); however, the mean values for apparent degree of doneness score increased ($P < 0.05$) as the percentage of fat in the ground beef patties increased. Also, as the mean end point temperature increased, the apparent degree of doneness increased (Table 3).

Color differences measurements

No differences attributable to treatment were found in HunterLab L mean values for the cooked ground beef patties. As the amount of fat increased, the HunterLab L mean value decreased in both ES and CC groups. Differences ($P < 0.05$) found among the fat levels were attributable to the ES samples with ES10 and ES20 having the highest and lowest mean values, respectively (Table 3). The HunterLab a mean values decreased as fat level increased in the ground beef patties (Table 3). Those results followed a trend similar to the apparent degree of doneness scores and the end point temperature mean values. No differences in HunterLab a values attributable to treatment combination were found. HunterLab b values were not affected by either treatment or fat level (Table 3).

Considering a coefficient between 0 to 0.39 low, 0.40 to 0.79 moderate and 0.80 to 1.00 high (Shindell, 1964), for three ground beef products there was a moderate correlation between apparent degree of doneness score and HunterLab a value (ES10, $r = -0.76^*$; ES20, $r = -0.43$; CC20, $r = -0.71^*$). For the other three ground beef products the correlation coefficients for those two measurements were low (ES15, $r = -0.030$; CC10, $r = -0.32$; CC15, $r = -0.37$).

pH and microbial counts of raw thawed ground beef

Mean values for pH of all thawed ground beef samples increased slightly as fat level increased. For the CC group there were no significant differences in pH among the fat levels; whereas, for the ES group there were significant differences among the three fat levels. In general, the ES samples had lower mean pH values than did the CC samples, the significant differences between ES and CC groups and among the fat levels were attributable to ES10 and ES15 samples (Table 4).

Data for log viable counts per gram of ground beef are given in Table 4. At each incubation temperature (type of microorganism-mesophilic, psychrotrophic, phychrophilic) for both ES and CC groups the log counts per gram decreased as the fat level increased. For the ES samples the differences among fat levels were not significant. The CC10 samples with the highest mean values were different ($P < 0.05$) from all other samples. The log viable counts per gram for both ES and CC groups were lower than the proposed bacteriological standards for ground beef (Goepfert, 1976; Pivnick et al., 1976). The results indicated that in general the ES group had lower log viable counts per gram at 32°, 25° or 5°C than the CC group; and that among the three incubation temperatures the incubation at 25°C gave the highest mean values which may indicate that at 25°C there was a better reflectance of the spoilage flora (psychrotrophic); although the individual identification was not made. Also, the pH for the ES samples was lower than that for the CC samples, which may influence the results for the microbial counts.

Table 4-Mean values, standard errors and LSDs for pH and log viable count per gram of raw ground beef

Measurements			Treatments[a] ES10	ES15	ES20	CC10	CC15	CC20	LSD[b]
pH	Fresh		5.70	5.89	6.03	5.87	5.90	5.93	
	Thawed	Mean	5.58	5.67	5.77c	5.74c	5.76c	5.77c	0.06
		S.E.	0.02	0.02	0.02	0.02	0.02	0.02	
Log viable counts/g at 32°C (mesophilic)	Fresh		4.66	4.41	4.30	5.25	5.24	4.98	
	Thawed	Mean	4.52c	4.50c	4.43c	5.72	4.73c	4.49c	0.34
		S.E.	0.12	0.12	0.12	0.12	0.12	0.12	
Log viable counts/g at 25°C (psychrotrophic)	Fresh		4.74	4.49	4.61	5.19	4.62	4.77	
	Thawed	Mean	4.64cd	4.58d	4.52d	5.76	4.85c	4.69cd	0.26
		S.E.	0.09	0.09	0.09	0.09	0.09	0.09	
Log viable counts/g at 5°C (psychrophilic)	Fresh		4.60	4.43	4.49	4.99	4.60	4.87	
	Thawed	Mean	4.42d	4.49cd	4.40d	5.27	4.66c	4.50cd	0.20
		S.E.	0.07	0.07	0.07	0.07	0.07	0.07	

[a]Treatments: CC10, 15, 20 = Conventionally chilled 10, 15, 20% fat; ES10, 15, 20 = Electrically stimulated 10, 15, 20% fat.

[b]Least significant difference at 5% level of probability. Means having the same letter (c-d) are not significantly different.

Color stability

For each time period, measurements for percentage reflectance (%R) were made at the following wavelengths: 474, 525, 571, 580, 614, 630nm; ratios were determined for 474/525, 571/525. Also, the difference for %R at 630nm-580nm was determined at each time period. K/S values were determined for wavelengths of 474, 525, 571nm, and for the ratios of 474/525 and 571/525.

The percentage reflectance ratios and the K/S data did not show any significant differences between ES and CC groups for any exposure time period. The F-values for effects of fat level are in Table 29, Appendix. In general, the significant differences found were atrributed to fat level for any exposure time period.

Percentage reflectance vs exposure time period. At each wavelength, the mean values for percentage reflectance at any exposure time period were not significantly different between ES and CC groups. However, there were differences ($P < 0.001$) among the fat levels for all time periods. The patterns at 474, 525 and 571nm for percentage reflectance were similar (Fig. 4, 5, 6). For each fat level, during 4 hours of exposure there were slight increases and decreases in reflectance, but the higher the fat level, the higher the percentage reflectance (Table 30, 31, 32, Appendix). Elliot (1967) stated that reflectance over the entire spectrum increases with increasing intramuscular fat, the effect being independent of wavelength.

Percentage reflectance at 630nm-580nm vs exposure time period (Fig. 7) showed significant differences at each time period (0 through 8) between ES and CC groups and among the fat levels. Those differences

Fig. 4 Changes in %R at 474nm for raw ground beef with three fat levels as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min.

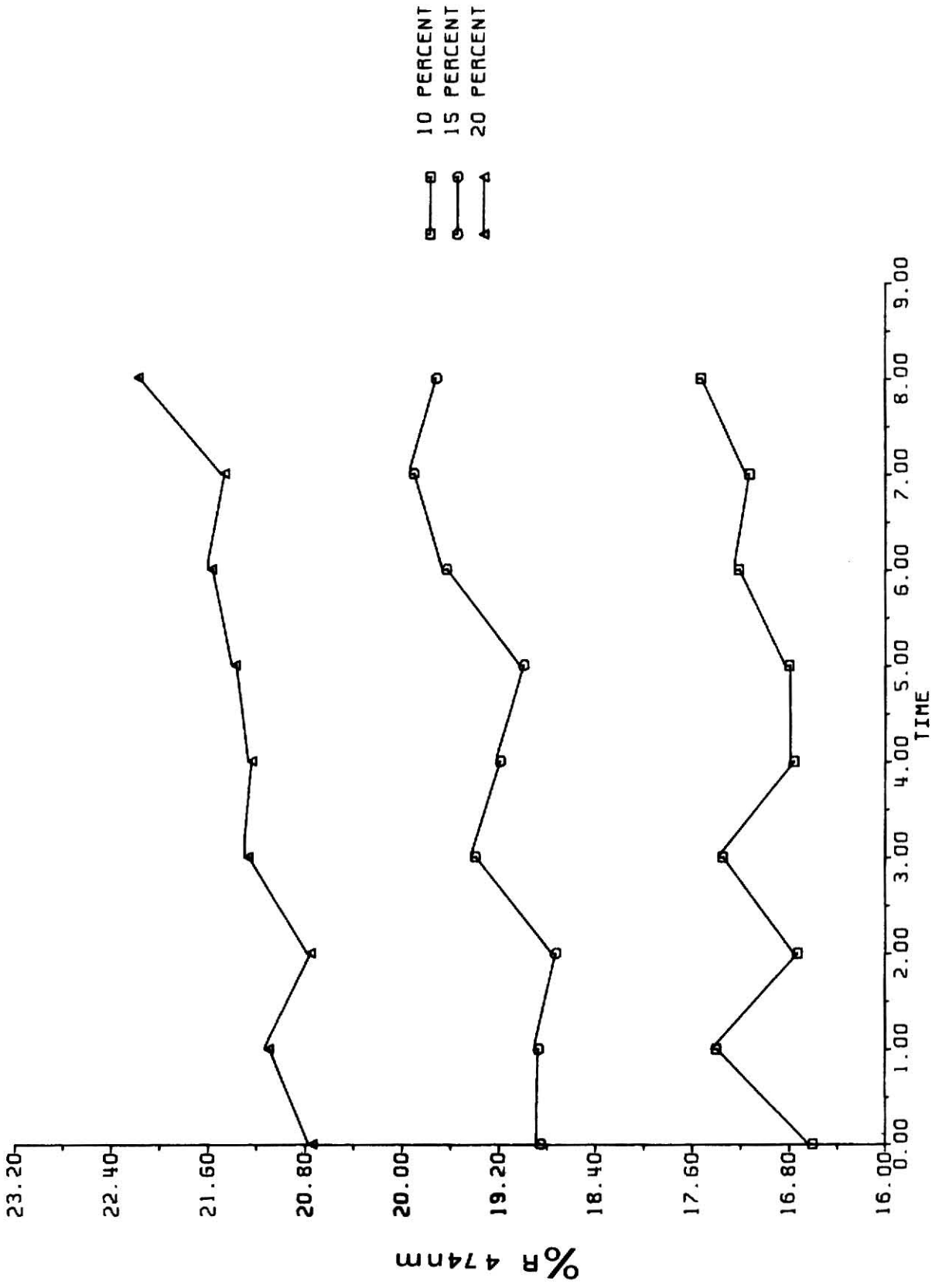

10 PERCENT
15 PERCENT
20 PERCENT
%R 474nm
TIME
23.20
22.40
21.60
20.80
20.00
19.20
18.40
17.60
16.80
16.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00

Fig. 5 Changes in %R at 525nm for raw ground beef with three fat levels as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min.

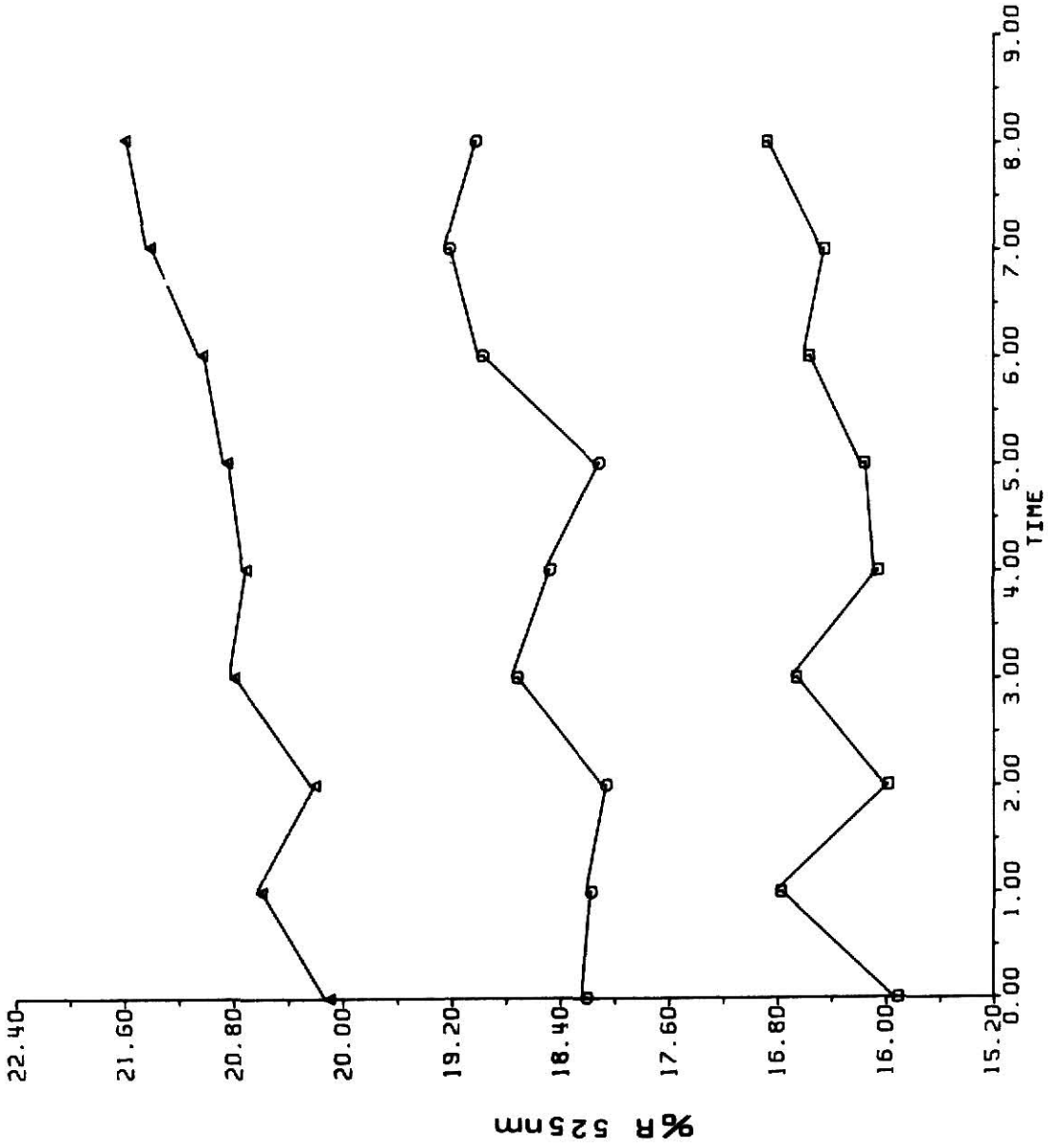

10 PERCENT FAT
15 PERCENT FAT
20 PERCENT FAT
%R 525nm
22.40
21.60
20.80
20.00
19.20
18.40
17.60
16.80
16.00
15.20
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
TIME

Fig. 6 Changes in %R at 571nm for raw ground beef with three fat levels as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min.

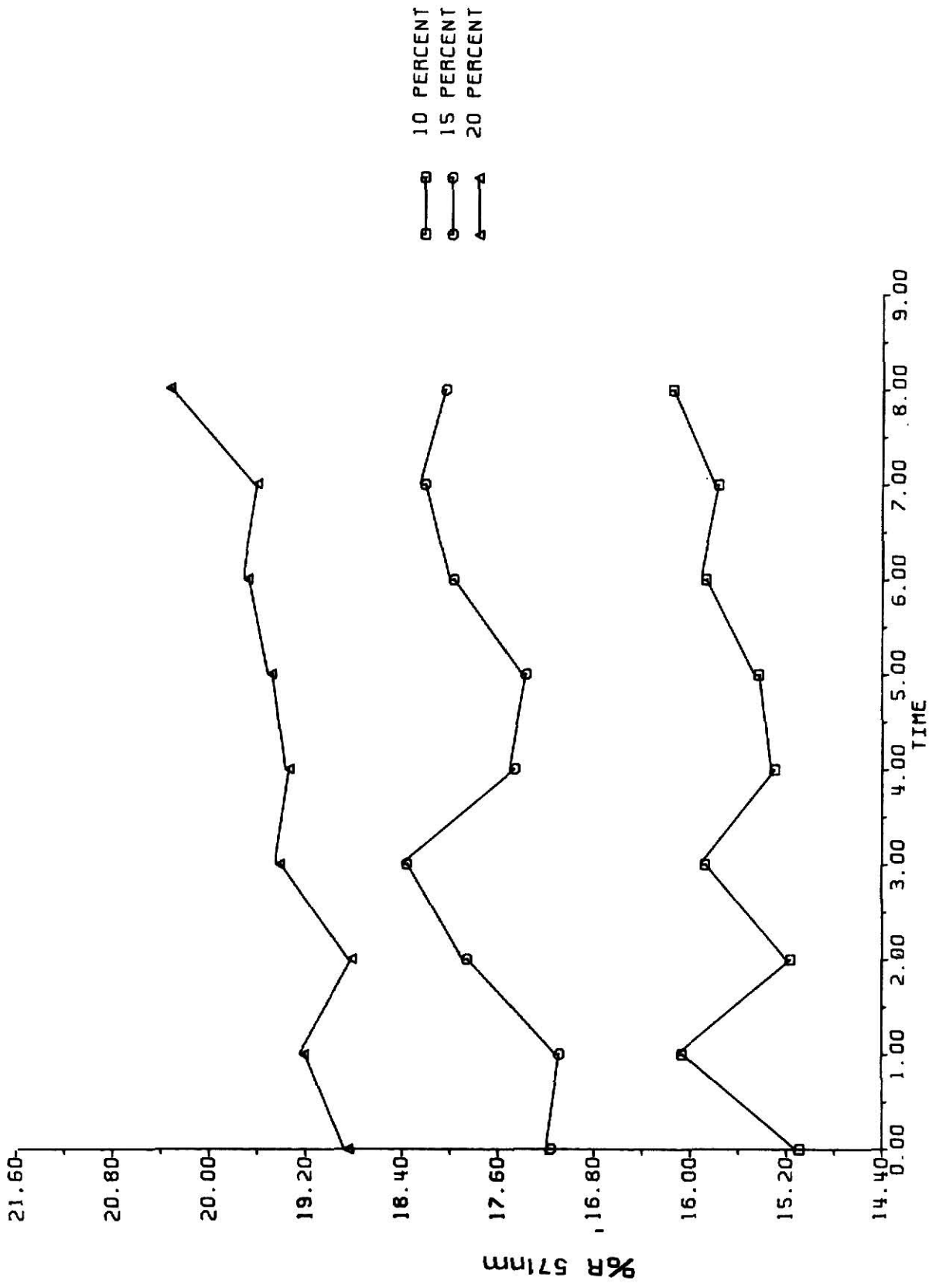
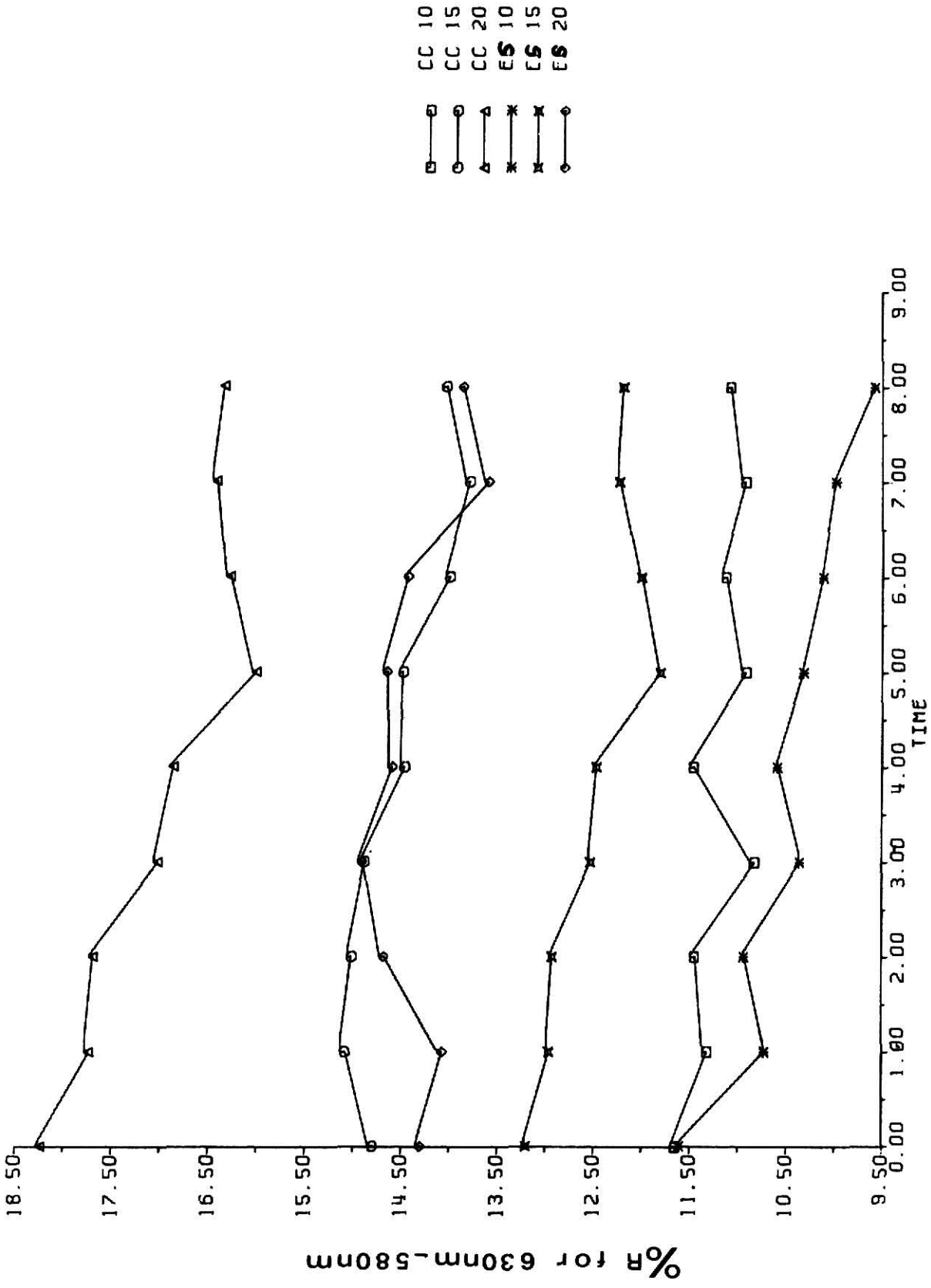

10 PERCENT
15 PERCENT
20 PERCENT
%R 571nm
21.60
20.80
20.00
19.20
18.40
17.60
16.80
16.00
15.20
14.40
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
TIME

Fig. 7 Changes in %R for 630nm-580nm for six raw ground beef products as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min.


CC 10
CC 15
CC 20
ES 10
ES 15
ES 20
%R for 630nm_580nm
18.50
17.50
16.50
15.50
14.50
13.50
12.50
11.50
10.50
9.50
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
TIME

($P < 0.05$) were attributable to the 20% fat samples (Table 33, Appendix). Lower percentage reflectance mean values were observed for the ES than for the CC group and in both ES and CC groups the samples with the higher fat content had the higher percentage reflectance (Table 33, Appendix). The differences between 8 and 0 time periods for percentage reflectance after 4 hours of exposure to radiant energy (Fig. 7; Table 35, Appendix) were significant among sample groups attributable to the 20% fat samples. ES10 samples had the greatest difference and CC10 samples the lowest, i.e., the color of ES10 samples changed most.

K/S ratio 571/525nm vs exposure time period. The K/S ratio 571/525 data in Table 5 indicated that during 4 hours of exposure (0 through 8 time periods) there was little change in K/S mean values for each of the fat levels. No significant differences were found that were attributable to treatment effect. Stewart et al. (1965a) found a linear relationship between percentage MetMb and K/S ratio based on their values for the ratio of 0.56 for 100% MetMb and 1.40 for 0% MetMb. Therefore, decreasing values for K/S 571/525 indicated an increase in MetMb formation. In this study, the K/S 571/525 mean values were between 1.12 and 1.06 (Table 5), which indicated a conversion of MbO_2 to MetMb. Also, the ratio of K/S 571/525 mean values increased slightly with increasing fat content of the sample (Table 5). Similarly, Van den Oord and Wesdorp (1971a) reported that the K/S values for 571/525 and 474/525 increased slightly as the fat content increased from 0 to 30% in ground meat samples.

HunterLab L, a and b values vs exposure time period. The HunterLab L and b values at each exposure time period did not show significant

Table 5-Mean values, standard errors and LSDs for the ratio K/S 571/525 vs exposure time period for raw ground beef

Exposure time period[a]		Level of fat			LSD[b]
		10	15	20	
0	Mean	1.07c	1.09cd	1.10d	0.020
	S.E.	0.007	0.007	0.007	
1	Mean	1.07c	1.09cd	1.10d	0.025
	S.E.	0.009	0.009	0.009	
2	Mean	1.07c	1.09cd	1.12d	0.030
	S.E.	0.010	0.010	0.010	
3	Mean	1.07c	1.09c	1.10c	----
	S.E.	0.015	0.015	0.015	
4	Mean	1.07c	1.09cd	1.12d	0.040
	S.E.	0.014	0.014	0.014	
5	Mean	1.07c	1.08cd	1.11c	----
	S.E.	0.057	0.057	0.057	
6	Mean	1.06c	1.08cd	1.11	0.025
	S.E.	0.009	0.009	0.009	
7	Mean	1.06c	1.08c	1.11	0.025
	S.E.	0.009	0.009	0.009	
8	Mean	1.06c	1.08cd	1.10d	0.030
	S.E.	0.010	0.010	0.010	

[a]Interval between each time period is equal to 30 min.

[b]Least significant difference at the 5% level of probability. Means having the same letter (c-d) are not significantly different.

differences attributable to treatment combination; however, significant differences occurred among the fat levels (Table 29, Appendix).

Figure 8 shows HunterLab a values plotted against exposure time period for all sample groups. The data of Figure 8 indicated that the HunterLab a values decreased for each treatment combination during 4 hours of exposure (0 through 8 time periods). Differences ($P < 0.05$) between 8 and 0 time periods for treatment groups (ES and CC) were attributable to the ES10 samples (Table 35, Appendix). At each time period there were differences ($P < 0.05$) between ES and CC groups and among the fat levels. After 4 hours of exposure, the significant differences between ES and CC groups and among the fat levels were caused by the CC20 and ES10 samples, which gave the highest and lowest HunterLab a mean values, respectively (Table 39, Appendix).

In general, the HunterLab a mean values for the ES group were lower than those for the CC group at any exposure time period. Contrary to what may be expected, the higher the fat level, the higher were the HunterLab a mean values within each group for any exposure time period (Table 39, Appendix). The amount of fat present in the sample may have interfered with the measurement of redness in the ground beef samples.

a/b ratio vs exposure time period. Figure 9 shows the curve for a/b ratio vs exposure time period. In general, there were increases and decreases for each treatment combination with CC15 haveing the greatest changes. Differences ($P < 0.05$) between 8 and 0 time periods were attributable to treatment effect (ES or CC). ES10 samples changed the most; whereas, the CC20 samples changed the least after 4 hours of exposure (Table 35, Appendix).

Fig. 8 Changes in HunterLab a values for six raw ground beef products as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min.

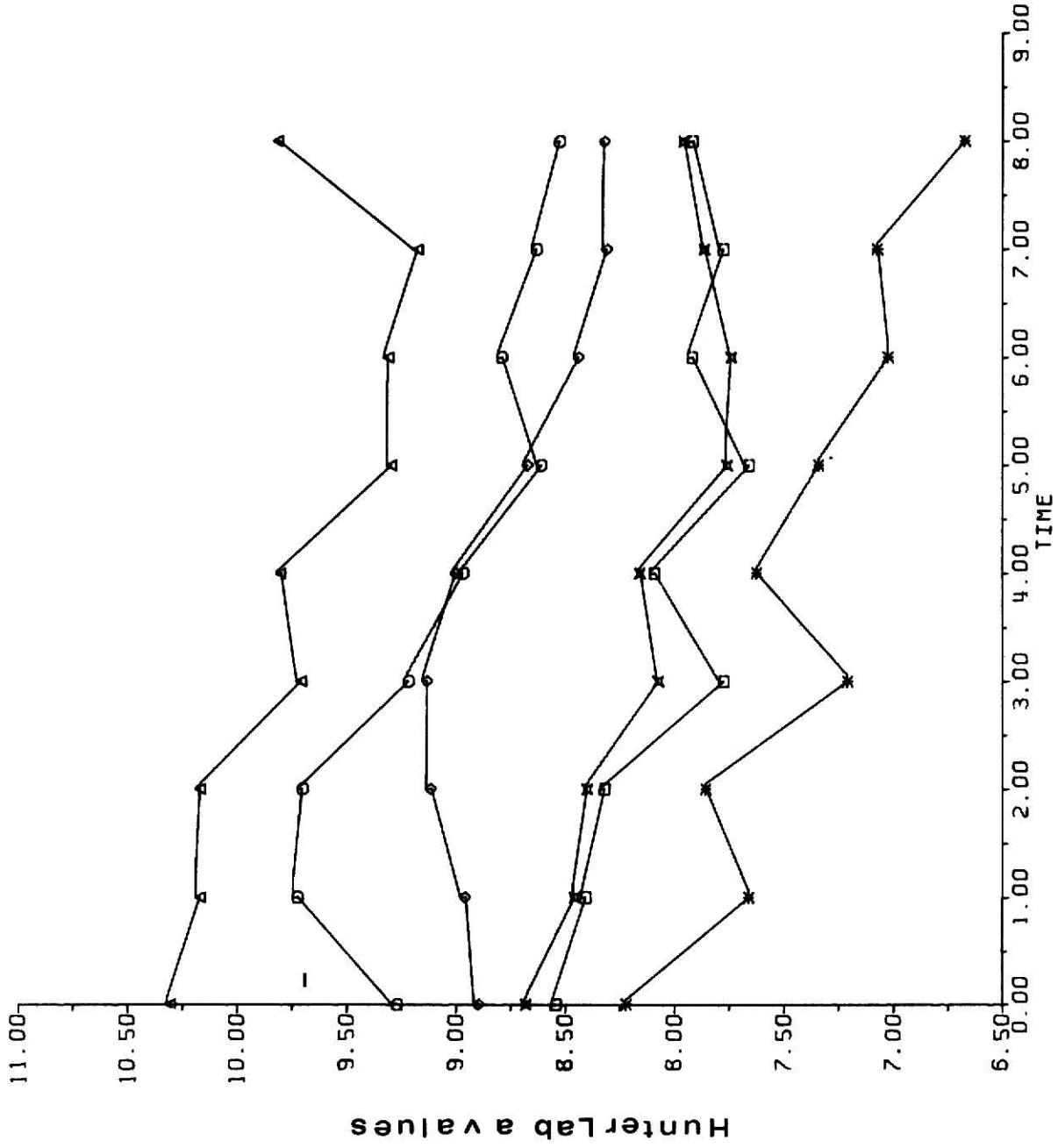
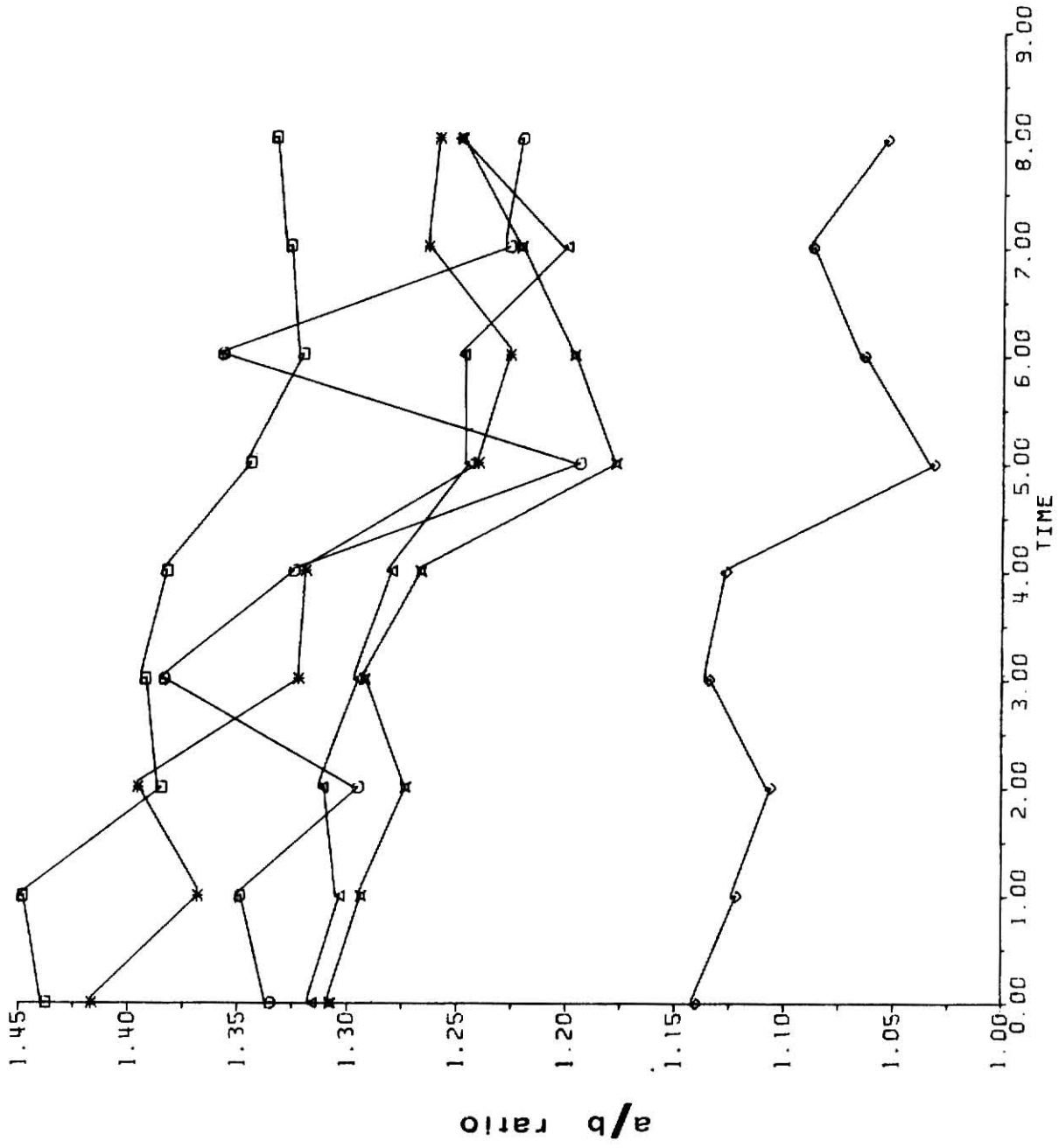

CC 10
CC 15
CC 20
ES 10
ES 15
ES 20
Hunter Lab a values
TIME
11.00
10.50
10.00
9.50
9.00
8.50
8.00
7.50
7.00
6.50
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00

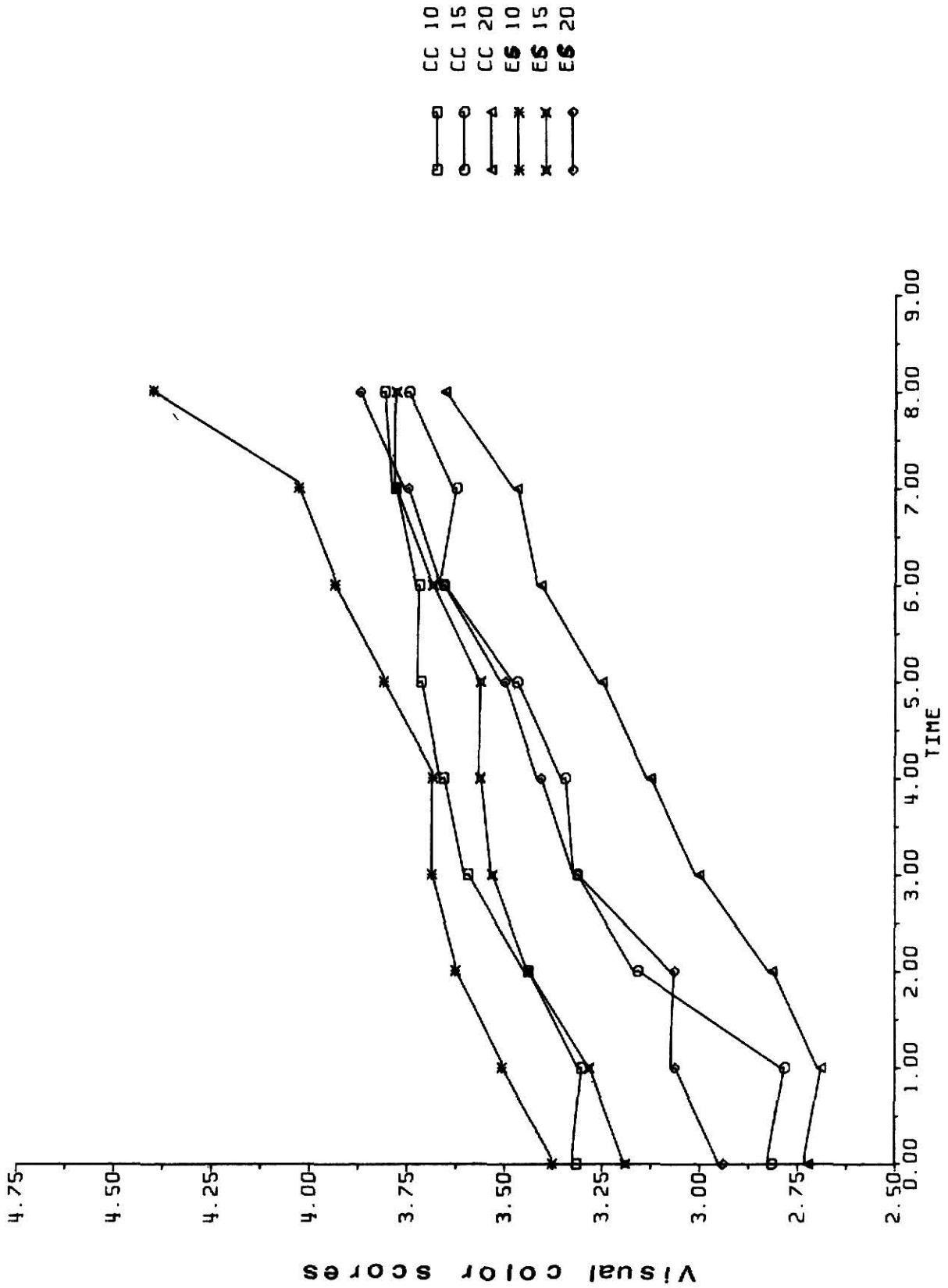
Fig. 9 Changes in the a/b ratio for six raw ground beef products as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min.


CC 10
CC 15
CC 20
ES 10
ES 15
ES 20
a/b ratio
TIME
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00

At each exposure time period the mean values for ES samples were consistently lower than those for the CC samples (Table 40, Appendix). The significant differences between ES and CC groups and among the fat levels could be attributed to the ES 20% fat samples which had the lowest mean a/b values at each exposure time period. A lower a/b value can be interpreted as color change attributable to MbO_2 or Mb being oxidized to MetMb, i.e., the ES samples with lower mean a/b values appear to be more sensitive to color changes than the CC samples.

Visual color scores vs exposure time period. Mean values for visual color scores vs exposure time period are shown in Figure 10. In general, for any treatment combination there was an increase in mean values for time period 0 through 8. The difference between 8 and 0 time was significant for all sample groups with ES10 having the greatest difference (Table 35, Appendix). Within the samples in the ES group, ES10 had the highest mean value for visual color scores and showed a marked increase in visual color scores after the seventh exposure time period (Fig. 10). Moreover, the evaluator consistently scored the samples with the highest percentage of fat as brighter ($P < 0.05$) than the leanest ones (Table 42, Appendix); but at the end of the 4 hours of exposure, there were no significant differences in visual color scores among all samples except for the ES10 sample (Table 41, Appendix), i.e., the ES10 samples appeared to the evaluator as darker in color or with a high amount of MetMb formation. The lamb color reference (Lamb Committee, undated) used by the evaluator appears to follow the progressive changes in color through 4 hours of exposure.

Fig. 10 Changes in visual color scores for six raw ground beef products as a function of exposure time to radiant energy. The interval between each time period is equal to 30 min. Visual color scale: 1 = very bright red, 2 = moderately bright red, 3 = slightly red, 4 = slightly grey, 5 = moderately grey and 6 = grey brown.


CC 10
CC 15
CC 20
ES 10
ES 15
ES 20
Visual color scores
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
TIME

HunterLab a values vs visual color scores. Figure 11 shows the curve for a values vs visual color scores at three fat levels. There was a reverse relationship between HunterLab a values and visual color scores, i.e., the lower the HunterLab a mean values, the darker the meat samples appeared to the evaluator. The 20% fat samples were scored brighter than the 15 or 10% fat samples. Although, the three curves did not follow the same pattern, there appears to be some relationship between HunterLab a values and visual color scores. These results may indicate that if lean ground beef has been in the market display case for some time, it may appear darker to consumers than ground beef containing more fat.

Relationships between selected color measurements

Correlation coefficients for selected color paired variates were calculated on the basis of treatment combination (Table 6). Considering a coefficient between 0 to 0.39 low, 0.40 to 0.79 moderate and 0.80 to 1.00 high (Shindell, 1964), correlation between %R for 630nm-580nm and HunterLab a values following 4 hours of exposure was high for ES10, ES15, and CC10, and moderate for ES20, CC15, and CC20. Correlation between %R for 630nm-580nm and a/b ratio indicated a moderate correlation for ES10, CC10, and CC20, high for ES15, and low for ES20 and CC15. Correlation between %R for 630nm-580nm and visual color scores was moderate for ES10, ES20, CC15, and CC20, and low for ES15 and CC10. Correlation between visual color scores and HunterLab a values following 4 hours of exposure was moderate for ES10, ES15, and CC15, and low for ES20, CC10, and CC20.

Correlation coefficients indicated that, in general HunterLab a values, a/b ratio, and visual color scores vs %R for 630nm-580nm followed

Fig. 11 Changes in HunterLab a values vs visual color scores for raw ground beef with three fat levels.

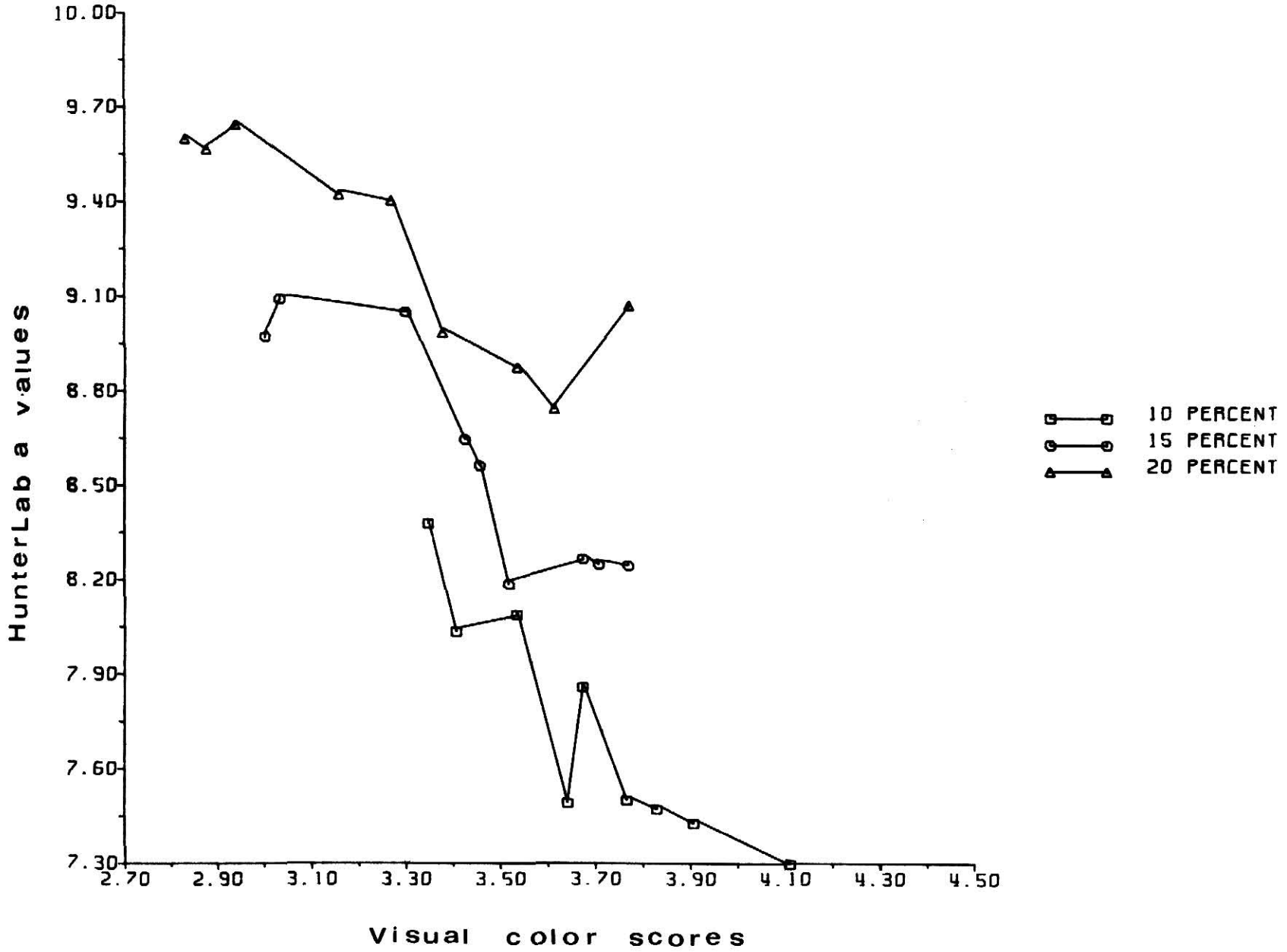

10.00
9.70
9.40
9.10
8.80
8.50
8.20
7.90
7.60
7.30
HunterLab a values
2.70
2.90
3.10
3.30
3.50
3.70
3.90
4.10
4.30
4.50
Visual color scores
10 PERCENT
15 PERCENT
20 PERCENT

Table 6-Correlation coefficients for selected color measurements of raw ground beef.

Paired variates df = 70	r - values[a] Treatments[b] ES10	ES15	ES20	CC10	CC15	CC20
%R (630nm - 580nm) vs.:						
HunterLab a values	0.86**	0.89**	0.65**	0.82**	0.76**	0.63**
Ratio $\frac{a}{b}$	0.41**	0.84**	0.15	0.44**	0.29**	0.55**
Visual color scores	-0.49**	-0.35**	-0.38**	-0.34**	-0.60**	-0.42**
Visual color scores vs.:						
HunterLab a values	-0.64**	-0.41**	-0.16	-0.27**	-0.48**	-0.19

[a]Levels of probability for 70 df: *P < 0.05, r = 0.232; **P < 0.01, r = 0.302.

[b]Treatments: CC10, 15, 20 = Conventionally chilled 10, 15, 20% fat; ES10, 15, 20 = Electrically stimulated 10, 15, 20% fat.

the progressive changes in color of the ground beef samples through 4 hours of exposure to radiant energy.

SUMMARY

Cattle of U.S. Choice and U.S. Good grades with weights between 410 and 500 kg were slaughtered, and at one hour after bleeding the right side of each carcass was electrically stimulated (ES, ca 600 volts, 5 amperes) for two min at a frequency of 60 cycles per second. The left side, non-stimulated control (conventionally chilled, CC) was placed in the cooler (5° ± 2°C) for 48 hr. At two hours postmortem beef flanks were removed from ES sides and divided into fat and lean. CC sides were handled the same as the hot boned, ES sides. Six ground beef products containing approximately 10, 15 or 20% fat were formulated. The products, fresh and thawed (storage at -30°C), were evaluated for cooking and sensory properties, objective measurements, pH, microbial counts, and color stability with a model system.

After 35 min cooking at 177°C, differences in end point temperature (ca 70°C) were not practical significant. There were no significant differences between ES and CC groups or among fat levels for the rate of heat penetration from the initial temperature in the patties to 70°C. In general, differences ($P < 0.05$) between ES and CC groups or among the fat levels for percentage total, volatile and drip losses could be attributed to the 20% fat samples.

Differences ($P < 0.05$) in total moisture in raw and cooked samples were attributable to fat level. For raw samples, no differences in total moisture were found between ES and CC groups. The ES samples usually contained less ($P < 0.05$) total moisture (cooked) than did CC samples.

Raw samples in the ES groups contained more ether extract than those in the CC group. In general, an increase in mean value for percentage of ether extract from raw to cooked was observed in both ES and CC groups. The pH for ES cooked samples was lower ($P < 0.05$) than that for CC samples; fat content did not affect pH of the cooked samples. Differences ($P < 0.05$) for total, serum, and fat press fluid were attributable to fat level. There were differences ($P < 0.05$) in flavor and juiciness scores between ES and CC groups with the ES group having more intense beef flavor and being slightly juicier. Differences ($P < 0.05$) for juiciness, tenderness and apparent degree of doneness were found among the fat levels with the two higher fat levels appearing more juicy, tender, and done. Texture was not affected significantly by ES and CC groups or fat level. HunterLab L value indicated darker samples with increased fat level of the cooked samples, and the HunterLab a value indicated less redness as the fat level increased. HunterLab b value did not change with an increase in fat level of the cooked samples.

For the raw products, the ES group had lower ($P < 0.05$) pH values than did the CC group. In general, differences ($P < 0.05$) in log viable counts per gram found for both ES and CC groups and among fat levels for any of the incubation temperatures (5°, 25°, 32°C) were attributable to the CC10 samples. The log counts per gram for both ES and CC groups were lower than the proposed bacteriological standard for ground beef. At each exposure time period, the difference ($P < 0.05$) in %R for 630nm-580nm for both ES and CC groups and among the fat levels were attributable to the 20% fat samples. After 4 hours of exposure to radiant energy, the ES10 samples changed the most. K/S ratio 571/525 indicated no differences between ES and CC groups, and little change among fat

levels. K/S ratio mean values increased with increasing fat content. HunterLab a value followed the MetMb formation through 4 hours of exposure to radiant energy. There was a high correlation between HunterLab a value and %R for 630nm-580nm for each of the treatment combinations. The higher the fat level, the higher the HunterLab a value; therefore, the amount of fat present may have interfered with the measurement of redness in the raw meat.

At each exposure time period, differences ($P < 0.05$) for a/b ratio between ES and CC groups and among fat levels were attributable to the 20% fat samples. ES samples with low a/b values appeared to be more sensitive to color changes than the CC samples. The moderate correlation coefficients between visual color scores and %R for 630nm-580nm indicated that the lamb color references followed the progressive changes in color of the ground beef samples through 4 hours of exposure to radiant energy. Moderate correlation occurred between the HunterLab a value and visual color score; and 20% fat samples were scored brighter than the 15 or 10% fat samples.

CONCLUSIONS

Under the conditions of this study, it was concluded that:

1. In general, the differences ($P < 0.05$) in cooking properties between ground beef prepared from ES and CC carcasses are attributable to the 20% fat samples.
2. pH for raw and cooked ES samples is lower ($P < 0.05$) than that for CC samples, and fat content does not affect pH of the cooked samples.
3. Flavor and juiciness are the only sensory properties for which there is a difference ($P < 0.05$) between ES and CC. The ES samples

have more intense beef flavor, and being slightly juicier than the CC samples.

4. The log viable counts per gram for both ES and CC groups are lower than the proposed bacteriological standard for ground beef.
5. The changes in color of ground beef with three fat levels through 4 hours of exposure to radiant energy are followed by the parameters %R for 630nm-580nm, HunterLab a value, a/b ratio, and visual color score.
6. The ES samples are more sensitive to color changes than the CC samples.

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APPENDIX

PERCENTAGE CALCULATIONS (PEARSON SQUARE)

Procedure to obtain a given percentage in a mixture with two raw materials is as follows:

One ingredient must have a percentage greater than the desired mixture and the other must have a percentage less than the desired mixture.

Example:

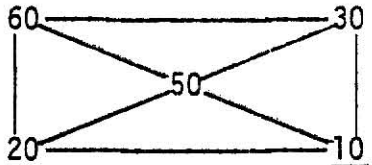
Ingredient A - 60% fat
Ingredient B - 20% fat
Fat percentage desired - 50%
Quantity desired - 100 lbs.

Solutions:

SQUARE METHOD

Ingredient A

Ingredient B



40 parts

Determine parts of ingredients to add by difference:

Parts of ingredient B: 60% in ingredient A (have) minus 50% (wanted) = 10 parts of B

Parts of ingredient A: 50% (wanted) minus 20% in ingredient B (have) = 30 parts of A

40 parts total

$\frac{30}{40}$ X 100 = 75 lbs. of 60% fat product (ingredient A)

100 lbs. of 50% fat product

$\frac{10}{40}$ X 100 = 25 lbs. of 20% fat product (ingredient B)

ALGEBRAIC METHOD

X = pounds of ingredient A (60% fat)
Y = pounds of ingredient B (20% fat)

First equation:..... X + Y = 100
Second equation:..... (.60X) + (.20Y) = 50%
Third equation: (second equation multiplied by 100:..... (60X) + (20Y) = 5000
Fourth equation (first equation multiplied by smallest number in third equation; in this case 20):. 20X + 20Y = 2000
Subtract fourth equation from third equation:..... 40X + 0Y = 3000
X = 75 pounds (ingredient A)
Substituting X in first equation:..... 75 + Y = 100 pounds
Y = 25 pounds (ingredient B)

Table 7-Randomized complete block design used to select ground beef samples for cooking, objective and subjective evaluations.

Day	Treatments[a]		
1[b]	4	5	3
2[b]	2	6	1
3[b]	6	4	2
4[b]	5	1	3
5[b]	5	4	3
6[b]	1	6	2
7[b]	3	5	2
8[b]	4	1	6
9	2	3	1
10	6	5	4
11	4	2	1
12	6	3	5
13	5	3	2
14	6	4	1
15	2	6	5
16	3	4	1

[a]Treatments: 1 = Electrically stimulated, hot boned, 10% fat.
2 = Electrically stimulated, hot boned, 15% fat.
3 = Electrically stimulated, hot boned, 20% fat.
4 = Conventionally chilled, 10% fat.
5 = Conventionally chilled, 15% fat.
6 = Conventionally chilled, 20% fat.

[b]Ether extract and total moisture determination.

Table 8-Completely randomized design used to select raw ground beef for color stability, pH and microbial counts.

	Treatments[a]				
	Days				
Week	1	2	3	4	5
1	4,5	3,2	6,1	6,4	2,5
2	1,3	5,4	3,1	6,2	3,5
3	2,4	1,6	2,3	1,6	5,4
4	4,2	1,6	3,5	5,3	2,6
5	4,1	2,6	5,3	4,1	

[a]Treatments: 1 = Electrically stimulated, hot-boned, 10% fat.
2 = Electrically stimulated, hot-boned, 15% fat.
3 = Electrically stimulated, hot boned, 20% fat.
4 = Conventionally chilled, 10% fat.
5 = Conventionally chilled, 15% fat.
6 = Conventionally chilled, 20% fat.

Fig. 12 Sampling plan for ground beef patties.

1-2 sensory evaluation

3 determination of: press fluid

total moisture

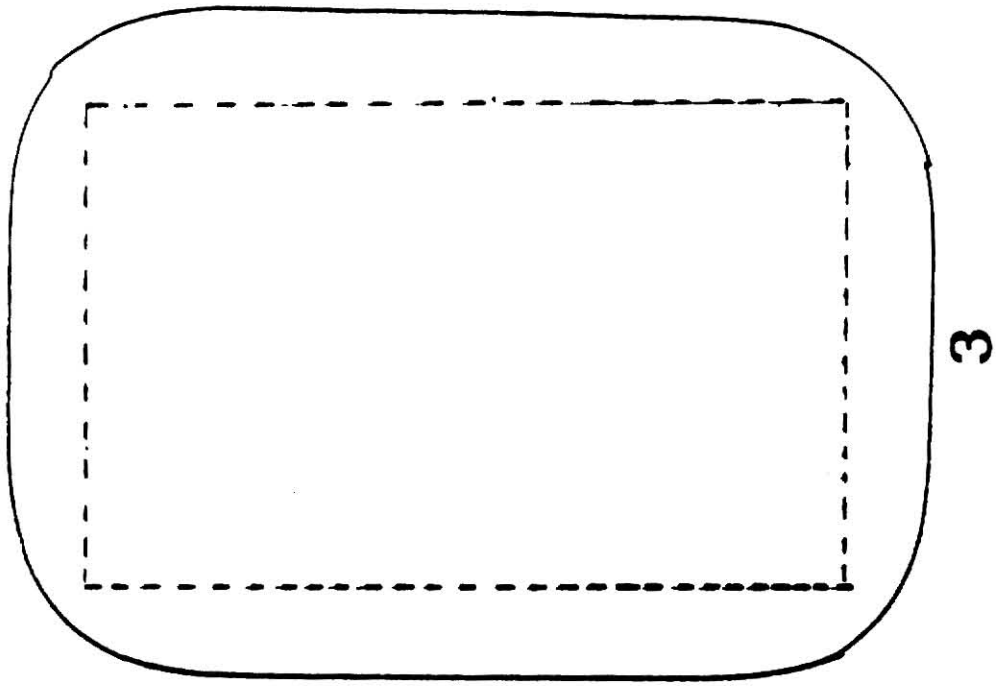
ether extract

color-differences

pH

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.



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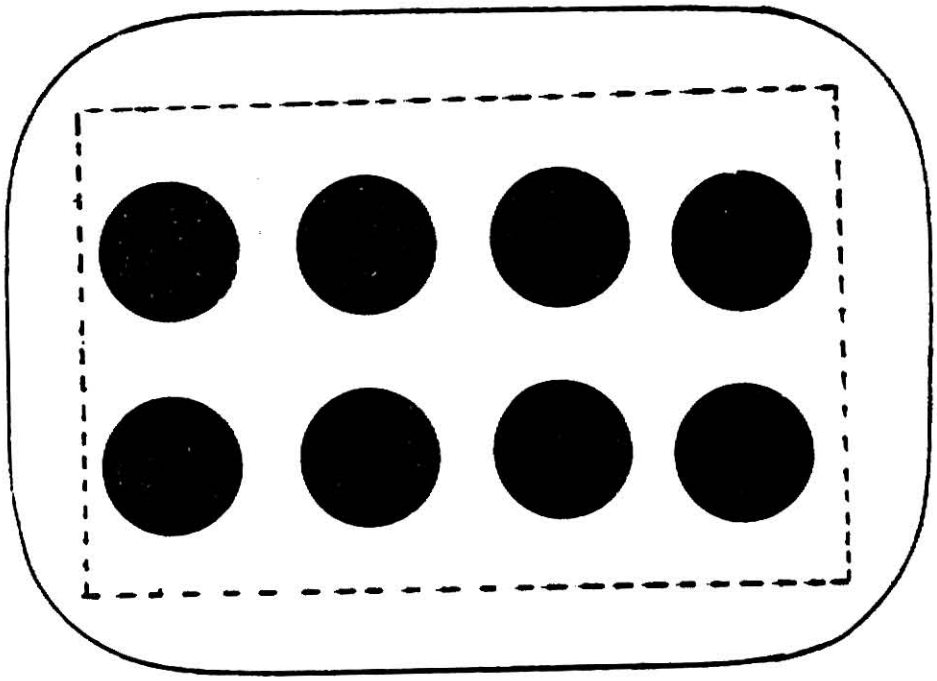

1 - 2

Form I

DEPARTMENT OF FOODS AND NUTRITION

PROJECT 0948

Instructions to Panel Members for Sensory Evaluation of Ground Beef

Select one sample (core) of ground beef from each double boiler. Use one-half of the core to score for flavor and juiciness; use the other half core to score for texture and tenderness.

Scoring

Record a score for flavor, juiciness, texture, or tenderness within the range of 5 to 1 that describes your impression of the sample. Refer to the score card for descriptive terms for given scores within the range of 5 to 1. For flavor and juiciness, record the score that describes your impression of the sample at the beginning of the chewing process; also, for juiciness, record a score after you have completed chewing (sustained score). For texture or tenderness, record the score that gives your impression of the sample after chewing.

Take your time to score each sample. Rinse your mouth with water between samples.

Apparent Doneness

All members of the panel observe the samples covered with household plastic wrap that are under the MacBeth Skylight. Record a score for each sample that describes your impression of the degree of doneness, i.e., well-done, medium-done, or rare. Use scores of 4 or 2 to indicate slightly more doneness than medium-done, but not well-done or slightly less done than medium-done, but not rare. Use the foot peddle on the right of the Skylight to adjust lighting conditions (daylight).

Comments

Comments about a sample or an explanation of your reason for giving a score are helpful.

Project 948 Foods & Nutrition SCORE CARD FOR GROUND BEEF

Form II

Panel member _____ Codes _____ Date _____

Please use the scales given below to score flavor, juiciness, texture, tenderness and apparent doneness of meat samples.

Sample code	Flavor score	Juiciness score		Texture score	Tenderness score	Apparent doneness score
		Initial	Sustained			

Flavor score

5 Intense beef flavor
4 Moderately intense beef flavor
3 Slightly intense beef flavor
2 Perceptible beef flavor
1 No beef flavor

Juiciness score

5 Juicy
4 Moderately juicy
3 Slightly juicy
2 Slightly dry
1 Dry

Texture score

5 Mealy (fine, friable texture)
4 Moderately mealy
3 Slightly mealy
2 Slightly chewy
1 Chewy (cohesive, coarse texture)

Tenderness score

5 Tender
4 Moderately tender
3 Slightly tender
2 Slightly tough
1 Tough

Apparent doneness score

5 Well-done
4
3 Medium-done
2
1 Rare

Comments

Press Fluid Yields--Carver Laboratory Press

1. Weight 25g ground meat.
2. Pack the cylinder as follows: Place a round piece of cheese cloth in bottom of the cylinder, then filter paper, 1/3 of ground meat, filter paper, 1/3 of ground meat, filter paper, 1/3 of ground meat, filter paper and disc. Place plunger type cover on cylinder.
3. Place filled cylinder on platform of Carver Laboratory Press.
4. Gradually increase pressure according to the following schedule:

Time, min	15 min Schedule
	pressure lb.
1	5,000
2	7,500
3	10,000
5	10,000
7	10,000
7 1/2	12,500
8	12,500
10	15,000
11	16,000
15	16,000

5. Release pressure and pour collected press fluid into graduated centrifuge tubes. Cover tubes with aluminum foil.
6. Place tubes in refrigerator and read the volume of total press fluid, serum, and fat the following day. Duplicate readings should be within 0.2 ml of each other.

Preparation and Exposure of Samples and Measurement of Reflectance Spectra

1. Place frozen samples in refrigerator. Thaw 4 hours.
2. Remove samples from refrigerator.
3. Wearing disposable plastic gloves, weigh 20g of the sample and place sample in metal sample holder.
4. Cover sample with plastic wrap.
5. Place each sample in individual Whirl-pak bags and return to refrigerator.
6. Turn on HunterLab Spectrophotometer, and allow the instrument to warm up 2 hours.
7. Connect 20% oxygen gas to sample chamber.
8. Turn on power (Oriel Optics, Model C-72-50-1). Adjust to 64 volts, 7 amps with lamp blower at 50% power using variable power regulator and with the vent to the lamp housing (Oriel Optics, Model C-60-50) 25% open. Place interference filter (577nm) in filter holder.
9. Position air blower to cool the filter; turn on.
10. Start gas (compressed air) flow.
11. Suspend copper coils for gas flow in a Dewar flask containing liquid nitrogen. Adjust gas flow and coil depth into the flask to maintain 40°F.
12. Standardize spectrophotometer using a white filter reference standard.
13. Remove sample to be exposed from refrigerator.
14. Determine color measurements by programming the spectrophotometer.

15. Determine visual color scores, using color photographs in "Lamb Color" as color references.
16. Place sample in the sample chamber with interference filter (577nm) in position. Expose the sample for 4 hours, taking reflectance readings and visual color scores every 30 min.

Table 9-Values[a] for objective and subjective measurements of fresh ground beef

Measurements	Treatments[b]					
	ES10	ES15	ES20	CC10	CC15	CC20
End-point internal temp, °C	70.70	68.70	69.30	69.00	70.30	70.70
Cooking losses, %						
Total	24.10	26.60	32.90	22.40	28.10	34.40
Volatile	18.90	18.30	17.90	17.90	19.40	18.90
Drip	5.20	8.30	15.00	4.50	8.70	15.50
Total moisture, %						
A.O.A.C., raw	74.08	66.13	52.06	74.66	68.30	63.75
A.O.A.C., cooked	67.52	58.29	60.45	67.03	61.96	57.87
Ether extract, %						
A.O.A.C., raw	8.73	16.71	35.24	5.38	11.59	16.70
A.O.A.C., cooked	8.28	16.32	17.39	7.97	14.61	18.61
Press fluid, ml/25g						
Total	8.60	8.80	7.00	7.90	7.70	6.20
Serum	7.50	6.60	5.40	7.00	4.50	3.00
Fat	1.10	2.20	1.60	0.90	3.20	3.20
pH, cooked	6.16	6.19	6.36	6.22	6.10	6.11
Sensory scores[c], 5-1						
Flavor	3.30	3.30	3.00	3.20	3.20	3.50

Table 9-(concluded)

Measurements	Treatments[b]					
	ES10	ES15	ES20	CC10	CC15	CC20
Sensory scores[c], 5-1						
Juiciness Initial	3.00	3.80	3.20	3.30	3.20	3.30
Sustained	3.00	3.50	3.20	3.30	3.00	3.50
Texture	3.30	3.00	3.70	3.30	3.30	3.50
Tenderness	3.70	3.80	3.50	4.50	3.50	3.50
Apparent degree[d] of doneness	2.50	3.00	3.70	2.70	3.20	3.20
Color differences-- HunterLab spectrophotometer						
L (lightness)	50.41	49.85	54.15	49.52	50.87	48.96
a+ (redness)	6.93	5.14	2.85	6.35	4.87	4.21
b+ (yellowness)	9.34	9.19	7.12	9.09	8.68	8.19

[a]One observation.

[b]Treatments: CC-10, 15 and 20 = Conventionally Chilled 10, 15 and 20% fat; ES-10, 15 and 20 = Electrically Stimulated 10, 15 and 20% fat.

[c]Range: 5 = intense beef flavor, juicy, mealy or tender; 1 = no beef flavor, dry, chewy or tough.

[d]5 = well done; 3 = medium done; 1 = rare.

Table 10-Rate of heat penetration

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Initial meat temp, °C					
1	13.3	12.3	9.3	9.7	9.7	11.0
2	13.7	9.7	15.3	12.3	14.3	9.7
3	9.0	10.3	10.3	10.0	11.3	8.3
4	11.3	8.3	10.7	12.0	7.7	12.0
5	9.3	10.0	13.0	10.0	8.3	8.3
6	10.0	9.7	10.0	11.0	11.3	8.3
7	11.7	14.0	11.7	11.0	13.7	13.0
8	12.3	10.0	11.0	11.0	10.0	10.0
Avg.	11.3	10.5	11.4	10.9	10.8	10.1
	Time (min) temp. increase 20°C					
1	6.0	7.0	8.0	5.5	6.0	8.0
2	5.0	7.0	6.5	5.0	4.5	5.5
3	5.0	6.5	4.5	5.0	5.0	7.5
4	6.5	7.5	6.0	5.5	9.0	6.0
5	7.5	8.0	7.5	3.2	2.4	3.0
6	9.0	5.0	5.0	6.0	5.0	5.0
7	5.5	4.0	4.0	5.5	4.0	5.5
8	5.5	5.0	5.5	5.5	5.0	4.5
Avg.	6.3	6.3	5.9	5.2	5.1	5.6

Table 10-(continued)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Time (min) temp. increase 30°C					
1	11.0	11.0	12.5	9.5	11.0	13.0
2	9.0	11.0	10.0	9.0	8.5	10.5
3	9.5	11.0	10.0	8.5	9.0	9.5
4	9.5	11.0	9.0	8.5	12.5	10.0
5	11.3	12.3	10.4	8.3	8.0	10.3
6	14.1	11.0	9.5	13.1	9.0	10.0
7	8.5	8.0	8.5	9.0	7.0	10.0
8	10.0	9.0	9.5	9.0	10.5	7.0
Avg.	10.4	10.5	9.9	9.4	9.4	10.0
	Time (min) temp. increase 40°C					
1	14.0	15.0	16.5	14.0	15.4	17.0
2	13.0	14.0	14.5	13.0	11.5	14.5
3	13.0	15.0	13.0	12.0	12.0	14.0
4	14.0	14.5	12.0	12.0	16.5	14.5
5	14.2	16.0	14.4	11.3	11.2	13.4
6	18.1	15.2	13.5	16.0	13.0	13.5
7	13.0	11.0	12.0	12.0	10.5	13.0
8	14.0	13.0	14.5	13.5	11.0	11.0
Avg.	14.2	14.2	13.8	13.0	12.6	13.9

Table 10-(continued)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Time (min) temp. increase 50°C					
1	18.0	18.5	21.0	19.0	20.2	22.0
2	17.5	18.0	18.0	18.0	15.5	18.0
3	18.0	20.0	17.0	17.0	18.0	19.0
4	19.0	18.5	17.0	16.5	21.5	19.5
5	19.0	20.3	18.4	15.2	16.0	17.0
6	22.4	20.0	17.0	21.3	17.0	17.5
7	18.5	14.0	14.5	18.0	13.5	18.0
8	18.0	17.5	17.5	18.0	16.0	16.0
Avg.	18.8	18.4	17.6	17.9	17.2	18.4
	Time (min) temp. increase 55°C					
1	21.0	22.0	23.0	21.0	24.0	24.0
2	19.5	20.0	21.0	19.5	18.0	20.0
3	20.0	22.0	19.0	20.0	19.5	21.0
4	21.0	22.0	18.5	19.5	24.0	21.0
5	21.4	23.1	21.3	20.3	21.2	22.2
6	25.1	22.0	20.0	24.1	19.0	20.0
7	21.0	18.0	18.5	20.5	18.0	22.0
8	20.5	19.5	19.0	21.0	19.0	18.5
Avg.	21.2	21.1	20.0	20.7	20.3	21.1

Table 10-(continued)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Time (min) temp. increase 60°C					
1	25.0	25.0	26.4	24.1	27.5	27.0
2	23.0	23.0	23.5	22.5	22.5	23.5
3	22.5	25.0	21.5	22.0	24.0	25.0
4	25.0	24.5	22.0	23.0	27.5	24.0
5	25.0	26.4	24.0	23.1	24.0	24.5
6	27.4	25.1	22.5	27.3	23.5	23.0
7	25.0	22.0	22.5	24.0	21.0	25.5
8	24.5	22.0	23.5	25.5	21.5	21.0
Avg.	24.7	24.1	23.2	23.9	23.9	24.2
	Time (min) temp. increase 65°C					
1	28.0	28.0	28.2	28.0	32.0	31.0
2	25.5	26.0	25.5	26.5	24.5	27.0
3	24.0	30.0	25.5	26.0	25.0	29.0
4	28.0	30.0	26.0	26.5	30.0	27.0
5	28.3	30.0	27.3	30.0	31.0	30.2
6	31.4	28.1	27.0	31.1	27.5	27.0
7	28.0	25.0	25.5	27.5	24.0	28.5
8	27.5	26.0	27.5	28.0	25.5	24.5
Avg.	27.6	27.9	26.6	28.0	27.4	28.0

Table 10-(concluded)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Time (min) temp. increase 70°C					
1	33.0	33.5	35.0	30.0	35.0	34.0
2	32.5	31.0	31.5	32.0	30.5	31.5
3	30.0	34.0	31.0	32.5	31.5	32.0
4	35.0	34.0	31.0	32.0	35.0	32.0
5	35.0	35.0	35.0	35.0	35.0	35.0
6	35.3	33.3	30.0	35.0	33.0	30.5
7	33.5	29.0	29.0	32.5	29.0	33.0
8	33.0	31.0	32.5	32.5	30.5	30.0
Avg.	33.4	32.6	31.9	32.7	32.4	32.3

[a]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 11-Analysis of variance for rate of heat penetration of thawed ground beef

Source of variation		DF	Mean Square	F
Initial raw meat temp., °C				
Replications		7	7.251	2.91*
Treatments		5		
ES vs CC	(A)	(1)	3.152	1.26
Fat %	(B)	(2)	0.866	0.35
A x B		(2)	2.532	1.02
Error		35	2.492	
Total		47		
Time (min) - increase temp. to 20°C				
Replications		7	3.106	1.61
Treatments		5		
ES vs CC	(A)	(1)	8.250	4.28*
Fat %	(B)	(2)	0.020	0.01
A x B		(2)	1.008	0.52
Error		35	1.928	
Total		47		
Time (min) - increase temp. to 30°C				
Replications		7	5.353	2.86**
Treatments		5		
ES vs CC	(A)	(1)	5.267	2.81
Fat %	(B)	(2)	0.080	0.04
A x B		(2)	1.812	0.97
Error		35	1.875	
Total		47		
Time (min) - increase temp. to 40°C				
Replications		7	7.174	3.47**
Treatments		5		
ES vs CC	(A)	(1)	9.720	4.70*
Fat %	(B)	(2)	0.679	0.33
A x B		(2)	2.929	1.42
Error		35	2.068	
Total		47		

Table 11-(continued)

Source of variation		DF	Mean Square	F
Time (min) - increase temp. to 50°C				
Replications		7	8.423	2.84*
Treatments		5		
ES vs CC	(A)	(1)	2.042	0.69
Fat %	(B)	(2)	1.288	0.43
A x B		(2)	4.640	1.57
Error		35	2.964	
Total		47		
Time (min) - increase temp. to 55°C				
Replications		7	7.440	3.08*
Treatments		5		
ES vs CC	(A)	(1)	0.025	0.01
Fat %	(B)	(2)	0.657	0.27
A x B		(2)	3.685	1.52
Error		35	2.417	
Total		47		
Time (min) - increase temp. to 60°C				
Replications		7	6.213	2.36*
Treatments		5		
ES vs CC	(A)	(1)	0.001	0.00
Fat %	(B)	(2)	1.413	0.54
A x B		(2)	2.963	1.12
Error		35	2.635	
Total		47		
Time (min) - increase temp. to 65°C				
Replications		7	12.067	3.91**
Treatments		5		
ES vs CC	(A)	(1)	2.521	0.82
Fat %	(B)	(2)	0.994	0.32
A x B		(2)	3.685	1.19
Error		35	3.089	
Total		47		

Table 11-(concluded)

Source of variation		DF	Mean Square	F
Time (min) - increase temp. to 70°C				
Replications		7	10.437	4.06**
Treatments		5		
ES vs CC	(A) (1)		0.350	0.14
Fat %	(B) (2)		3.908	1.52
A x B	(2)		1.210	0.47
Error		35	2.571	
Total		47		

* P < 0.05

** P < 0.01

*** P < 0.001

Table 12-Endpoint internal temperature, °C and pH[a]

Replication	Treatments[b]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Endpoint internal temperature, °C					
1	70.70	70.70	70.00	70.70	68.70	72.30
2	71.30	72.00	72.00	72.30	73.00	70.70
3	70.00	71.00	74.70	71.70	73.30	71.00
4	70.70	72.30	72.70	69.70	72.00	73.00
5	69.70	68.60	70.30	70.00	71.30	69.30
6	70.00	70.00	74.00	71.30	70.30	73.70
7	70.30	71.00	73.70	71.70	73.30	71.70
8	73.70	72.00	73.30	69.70	73.70	74.00
Avg.	70.80	70.90	72.60	70.80	71.90	71.90
	pH[a]					
1	5.91	5.88	5.89	5.99	6.02	6.11
2	6.01	6.01	6.07	6.50	5.97	6.00
3	5.98	6.04	6.08	6.03	6.00	6.05
4	5.89	6.01	5.97	6.02	6.08	5.95
5	5.88	6.06	5.95	6.02	5.94	6.06
6	5.96	5.88	5.97	6.00	6.00	6.01
7	5.97	5.99	5.98	5.91	5.95	6.07
8	6.04	5.93	5.98	6.06	5.97	6.03
Avg.	5.96	5.98	5.99	6.07	5.99	6.04

[a]Cooked ground beef patties.

[b]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 13-Percentage cooking losses -total, volatile and drip

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Total, %					
1	24.10	25.90	34.10	27.00	26.30	36.70
2	24.60	33.80	38.80	29.40	28.90	34.60
3	26.60	30.00	38.10	27.50	28.30	32.90
4	25.20	31.60	34.20	23.90	28.80	32.70
5	24.80	26.90	33.90	23.50	26.70	30.70
6	27.90	28.30	37.70	25.10	30.10	33.10
7	27.70	33.10	36.40	25.00	29.40	32.70
8	26.90	29.40	35.90	26.10	28.10	33.10
Avg.	25.90	29.90	36.10	25.90	28.30	33.30
	Volatile, %					
1	21.30	21.90	18.90	22.20	20.00	19.80
2	21.50	22.80	20.40	22.60	22.40	19.80
3	22.20	22.00	22.40	23.90	22.80	19.80
4	22.60	23.10	20.60	21.90	21.10	20.40
5	23.30	21.10	19.40	20.90	20.40	18.90
6	21.90	20.60	21.70	21.30	23.50	11.50
7	23.10	25.60	21.20	22.40	22.60	20.60
8	23.90	22.00	20.20	22.20	20.20	20.60
Avg.	22.50	22.40	20.70	22.20	21.60	18.90

Table 13-(concluded)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Drip, %					
1	3.10	7.40	16.90	5.00	3.50	13.30
2	2.40	8.50	15.60	4.80	5.20	12.20
3	3.30	6.90	14.30	3.10	2.60	12.40
4	2.60	7.20	12.60	3.50	6.50	11.90
5	4.10	5.40	13.50	2.80	6.10	11.50
6	4.30	7.00	15.20	3.10	6.10	20.70
7	3.30	6.90	14.60	2.60	5.90	11.90
8	2.60	6.30	14.80	3.30	5.70	12.80
Avg.	3.20	6.90	14.70	3.50	5.20	13.30

[a]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 14-Percentage total moisture, raw and cooked ground beef patties

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Total moisture, %, A.O.A.C., raw					
1	70.46	66.04	56.01	71.72	68.48	59.28
2	64.18	66.36	58.56	63.64	61.79	55.60
3	76.41	65.64	59.19	72.40	69.92	60.68
4	73.73	66.93	59.78	73.25	64.54	58.40
5	-----	-----	-----	-----	-----	-----
6	-----	-----	-----	-----	-----	-----
7	-----	-----	-----	-----	-----	-----
8	-----	-----	-----	-----	-----	-----
Avg.	71.20	66.24	58.38	70.25	66.18	58.49
	Total moisture, %, A.O.A.C., cooked					
1	64.90	60.09	48.01	63.88	64.28	59.94
2	73.40	59.92	57.91	73.00	66.59	62.48
3	63.87	62.60	56.28	64.63	61.92	58.81
4	66.98	59.83	59.34	67.94	59.90	59.26
5	-----	-----	-----	-----	-----	-----
6	-----	-----	-----	-----	-----	-----
7	-----	-----	-----	-----	-----	-----
8	-----	-----	-----	-----	-----	-----
Avg.	67.29	60.61	55.39	67.36	63.17	60.12

Table 14-(concluded)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Total moisture, %, Brabender, cooked					
1	62.20	56.70	51.10	65.00	57.40	52.10
2	63.40	54.40	54.20	63.00	58.70	54.90
3	63.30	56.80	52.60	63.80	58.80	55.00
4	62.90	56.40	52.20	64.80	56.60	55.30
5	63.80	55.50	54.90	64.90	58.30	53.50
6	63.00	55.40	51.70	64.10	57.50	55.80
7	63.40	56.20	54.30	64.40	58.20	52.50
8	62.90	58.30	53.50	63.40	58.20	54.50
Avg.	63.11	56.21	53.06	64.18	57.96	54.20

[a]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 15-Percentage ether extract, raw and cooked ground beef patties

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Ether extract, % raw					
1	11.22	15.86	30.02	6.89	13.16	23.53
2	9.55	15.41	17.26	7.60	12.73	18.34
3	7.05	16.84	27.40	6.12	10.38	23.82
4	6.56	15.22	27.12	6.05	15.51	24.61
5	----	-----	-----	----	-----	-----
6	----	-----	-----	----	-----	-----
7	----	-----	-----	----	-----	-----
8	----	-----	-----	----	-----	-----
Avg.	8.60	15.83	25.45	6.67	12.95	22.58
	Ether extract, % cooked					
1	10.87	14.05	20.22	7.83	10.68	15.58
2	6.35	16.25	28.88	6.78	14.67	20.17
3	9.06	15.69	20.13	7.90	12.86	16.57
4	9.56	16.79	19.20	7.24	16.79	16.97
5	----	-----	-----	----	-----	-----
6	----	-----	-----	----	-----	-----
7	----	-----	-----	----	-----	-----
8	----	-----	-----	----	-----	-----
Avg.	8.96	15.70	22.11	7.44	13.75	17.32

[a]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 16-Press fluid, ml/25g -total, serum and fat

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Total, ml/25g					
1	8.10	8.00	8.00	8.80	8.90	8.00
2	8.30	7.90	8.00	9.20	8.40	6.90
3	7.60	9.00	8.00	8.10	7.10	7.40
4	9.40	8.80	9.00	8.00	8.10	8.50
5	8.80	9.00	7.90	8.90	8.70	8.10
6	8.90	8.80	7.80	8.90	8.80	8.30
7	8.90	8.00	7.80	8.80	7.00	8.10
8	8.30	9.70	8.00	9.00	8.30	8.80
Avg.	8.50	8.70	8.10	8.70	8.20	8.00
	Serum, ml/25g					
1	7.00	5.10	5.50	7.70	6.60	4.50
2	7.30	5.30	4.50	8.10	5.60	2.50
3	6.80	6.30	4.70	6.70	5.40	5.00
4	8.00	3.80	5.70	6.80	6.30	4.50
5	7.60	6.40	5.40	7.80	6.50	5.40
6	7.30	6.30	4.30	7.80	7.00	4.60
7	8.10	5.20	3.90	7.40	4.90	5.20
8	7.30	7.10	5.10	7.90	6.20	5.90
Avg.	7.40	5.70	4.90	7.50	6.10	4.70

Table 16-(concluded)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Fat, ml/25g					
1	1.10	2.90	2.50	1.10	2.30	3.50
2	1.00	2.60	3.50	1.10	2.80	4.50
3	0.80	2.80	3.30	1.40	1.70	2.40
4	1.40	5.00	3.30	1.20	1.80	4.00
5	1.20	2.60	1.50	1.10	2.20	2.70
6	1.60	2.50	3.50	1.10	1.80	3.70
7	0.80	2.80	3.90	1.40	2.10	2.90
8	1.00	2.60	2.90	1.10	2.10	2.90
Avg.	1.10	2.90	3.00	1.20	2.10	3.30

[a]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 17-Sensory scores for flavor[a], juiciness[b] initial and sustained

Replication	Treatments[c]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Flavor[a]					
1	3.60	3.70	3.30	2.70	3.60	3.40
2	3.30	2.70	3.80	3.40	2.50	3.00
3	3.00	3.00	3.50	2.70	2.80	3.20
4	2.70	3.70	3.00	2.80	3.20	2.80
5	3.40	3.60	3.80	2.80	3.20	3.20
6	3.30	4.20	3.70	3.20	3.40	3.30
7	3.30	2.80	3.30	3.30	3.20	3.00
8	3.00	3.40	3.60	2.70	3.10	3.00
Avg.	3.20	3.40	3.50	2.90	3.10	3.10
	Juiciness[b], initial					
1	2.70	3.40	3.70	2.60	3.60	3.30
2	2.20	3.70	3.00	2.90	2.30	3.30
3	3.20	4.30	4.30	2.80	3.30	3.30
4	2.80	4.00	4.20	3.00	2.80	3.40
5	3.60	3.80	3.80	2.40	3.00	4.00
6	3.20	4.30	3.30	3.40	3.80	3.40
7	2.60	3.50	4.00	3.30	2.70	3.60
8	2.60	3.60	3.40	2.40	3.70	3.30
Avg.	2.80	3.80	3.70	2.90	3.20	3.50

Table 17-(concluded)

Replication	Treatments[c]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Juiciness[b], sustained					
1	2.60	3.40	3.90	2.70	3.40	3.60
2	2.50	3.50	2.80	3.10	2.50	3.20
3	2.80	3.70	3.80	3.20	3.20	3.30
4	2.60	3.50	3.80	3.00	3.00	3.00
5	3.20	3.20	3.40	2.80	3.00	4.00
6	3.30	4.00	4.00	3.20	2.40	3.40
7	3.00	3.20	4.00	3.30	2.70	3.10
8	2.90	3.60	3.40	2.70	3.10	3.30
Avg.	2.80	3.50	3.60	3.00	2.90	3.40

[a]Range, 5 = intense beef flavor; 1 = no beef flavor.

[b]Range, 5 = juicy; 1 = dry.

[c]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 18-Sensory scores for texture[a], tenderness[b] and apparent degree of doneness[c]

Replication	Treatments[d]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Texture[a]					
1	3.10	3.00	3.70	3.00	3.40	3.00
2	3.20	3.80	3.00	2.90	3.30	3.70
3	2.70	3.20	2.80	3.50	3.30	3.00
4	2.80	3.20	3.30	3.00	3.20	3.40
5	3.00	3.20	3.40	3.00	2.80	3.00
6	3.20	3.30	2.70	2.80	3.00	2.90
7	3.30	2.70	3.30	2.80	2.80	3.00
8	2.90	3.40	3.30	2.90	3.40	3.60
Avg.	3.00	3.20	3.10	3.00	3.10	3.20
	Tenderness[b]					
1	3.30	3.60	4.10	3.00	3.90	3.40
2	3.30	3.80	3.80	3.40	3.70	3.80
3	3.50	4.00	3.50	3.50	3.20	3.30
4	3.60	3.70	4.00	3.00	3.20	4.00
5	3.80	3.40	3.80	3.80	3.40	3.80
6	3.00	3.50	3.70	3.40	3.30	3.40
7	3.70	3.30	3.50	3.20	2.80	3.70
8	3.10	3.60	3.60	3.30	3.40	3.70
Avg.	3.40	3.60	3.70	3.30	3.30	3.60

Table 18-(concluded)

Replication	Treatments[d]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Apparent degree of doneness[c]					
1	3.30	3.70	3.60	3.70	4.00	3.70
2	3.70	2.80	4.20	3.40	4.00	3.80
3	3.50	3.80	4.50	3.00	4.20	4.20
4	3.20	4.30	4.30	4.20	4.20	4.40
5	3.80	4.20	4.40	3.60	4.20	4.40
6	3.00	3.80	4.10	3.20	4.00	4.10
7	3.10	4.30	4.30	4.00	4.30	4.00
8	3.70	3.30	4.30	3.90	4.00	3.90
Avg.	3.40	3.70	4.20	3.60	4.10	4.00

[a]Range, 5 = mealy; 1 = chewy.

[b]Range, 5 = tender; 1 = tough.

[c]Range, 5 = well-done; 1 = rare.

[d]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 19-Color differences measurements, HunterLab L, a and b values

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	L value (lightness)					
1	47.88	48.05	47.91	48.18	50.11	49.46
2	49.26	46.71	47.35	46.08	47.81	48.20
3	48.09	47.94	46.57	49.19	48.89	46.92
4	47.47	47.80	45.65	50.55	48.43	47.49
5	46.06	48.73	47.61	47.05	48.30	47.35
6	51.23	48.23	47.28	49.32	47.04	47.51
7	49.04	47.94	47.60	48.40	46.41	46.30
8	49.47	48.20	46.67	46.99	46.17	47.26
Avg.	48.56	47.95	47.08	48.22	47.89	47.56
	a value (redness)					
1	4.45	9.25	3.57	3.86	4.35	4.55
2	4.63	3.47	3.58	4.17	3.95	4.29
3	4.50	4.40	3.85	5.41	3.91	3.82
4	4.73	4.60	3.79	6.36	3.77	3.78
5	3.92	3.61	3.51	4.04	4.36	3.72
6	6.65	5.08	3.48	4.14	3.88	3.47
7	5.39	4.41	3.62	5.10	3.55	3.57
8	4.70	4.65	3.63	4.22	3.90	4.28
Avg.	4.87	4.31	3.63	4.66	3.96	3.94

Table 19-(concluded)

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	b value (yellowness)					
1	8.56	8.00	7.99	8.36	9.42	8.51
2	9.07	8.71	8.33	7.96	8.73	9.07
3	9.07	8.64	8.51	9.76	8.79	8.64
4	8.46	8.92	8.56	9.67	8.57	8.62
5	7.52	8.78	8.75	8.46	9.29	8.84
6	9.64	9.38	3.43	8.87	7.98	8.67
7	9.06	8.63	8.75	9.50	7.94	7.94
8	9.40	8.87	8.28	8.59	8.03	8.56
Avg.	8.85	8.74	8.45	8.90	8.59	8.60

[a]Treatments: CC-10, 15 and 20 = Conventionally Chilled, 10, 15 and 20% fat. ES-10, 15 and 20 = Electrically Stimulated, 10, 15 and 20% fat.

Table 20-Analysis of variance for objective and subjective measurements of thawed ground beef

Source of Variation		DF	Mean Square	F
End-point internal temp., °C				
Replications		7	4.937	3.17**
Treatments		5		
ES vs CC	(A)	(1)	0.285	0.18
Fat %	(B)	(2)	8.258	5.30**
A x B		(2)	2.654	1.70
Error		35	1.559	
Total		47		
Cooking Losses, %, total				
Replications		7	8.706	3.15**
Treatments		5		
ES vs CC	(A)	(1)	25.960	9.38**
Fat %	(B)	(2)	315.773	114.14***
A x B		(2)	7.789	2.82
Error		35	2.767	
Total		47		
Volatile				
Replications		7	4.226	1.73
Treatments		5		
ES vs CC	(A)	(1)	10.641	4.35*
Fat %	(B)	(2)	30.095	12.30***
A x B		(2)	2.235	0.91
Error		35	2.447	
Total		47		
Drip				
Replications		7	3.360	1.46
Treatments		5		
ES vs CC	(A)	(1)	10.360	4.49*
Fat %	(B)	(2)	489.646	212.13***
A x B		(2)	4.785	2.07
Error		35	2.308	
Total		47		

Table 20-(continued)

Source of variation		DF	Mean Square	F
Total moisture, % raw				
A.O.A.C.				
Replications		3	35.738	5.37**
Treatments		5		
ES vs CC	(A) (1)		0.537	0.08
Fat %	(B) (2)		309.006	46.44***
A x B	(2)		0.635	0.10
Error		15	6.654	
Total		23		
Total moisture, % cooked				
A.O.A.C.				
Replications		3	31.897	3.78*
Treatments		5		
ES vs CC	(A) (1)		36.260	4.30*
Fat %	(B) (2)		184.338	21.84***
A x B	(2)		10.886	1.29
Error		15	8.441	
Total		23		
Total moisture, % cooked				
Brabender				
Replications		7	0.744	0.66
Treatments		5		
ES vs CC	(A) (1)		20.803	18.53***
Fat %	(B) (2)		413.814	368.50***
A x B	(2)		0.569	0.51
Error		35	1.123	
Total		47		
Ether extract, % raw, A.O.A.C.				
Replications		3	11.574	1.51
Treatments		5		
ES vs CC	(A) (1)		39.450	5.14*
Fat %	(B) (2)		542.245	70.65***
A x B	(2)		0.604	0.08
Error		15	7.675	
Total		23		

Table 20-(continued)

Source of variation		DF	Mean Square	F
Ether extract, % cooked, A.O.A.C.				
Replications		3	6.044	0.90
Treatments		5		
ES vs CC	(A) (1)		45.403	7.43**
Fat %	(B) (2)		266.811	43.65***
A x B	(2)		6.296	1.03
Error		15	6.112	
Total		23		
pH, cooked				
Replications		7	0.011	1.39
Treatments		5		
ES vs CC	(A) (1)		0.041	5.40*
Fat %	(B) (2)		0.004	0.53
A x B	(2)		0.009	1.22
Error		35	0.008	
Total		47		
Press fluid, ml/25g Total				
Replications		7	0.553	1.96
Treatments		5		
ES vs CC	(A) (1)		0.175	0.62
Fat %	(B) (2)		1.411	4.99**
A x B	(2)		0.454	1.60
Error		35	0.283	
Total		47		
Press fluid, ml/25g Serum				
Replications		7	0.811	1.52
Treatments		5		
ES vs CC	(A) (1)		0.110	0.21
Fat %	(B) (2)		29.115	54.58***
A x B	(2)		0.317	0.59
Error		35	0.533	
Total		47		

Table 20-(continued)

Source of variation		DF	Mean Square	F
Press fluid, ml/25g				
Fat				
Replications		7	0.506	1.70
Treatments		5		
ES vs CC	(A) (1)		0.368	1.23
Fat %	(B) (2)		17.331	58.19***
A x B	(2)		1.510	5.07
Error		35	0.298	
Total		47		
Sensory score, flavor				
Replications		7	0.188	1.96
Treatments		5		
ES vs CC	(A) (1)		1.080	11.21*
Fat %	(B) (2)		0.237	2.46
A x B	(2)		0.023	0.24
Error		35	0.096	
Total		47		
Sensory score, juiciness, initial				
Replications		7	0.284	1.95
Treatments		5		
ES vs CC	(A) (1)		1.203	8.24**
Fat %	(B) (2)		2.488	17.04***
A x B	(2)		0.448	3.07
Error		35	0.146	
Total		47		
Sensory score, juiciness, sustained				
Replications		7	0.114	1.17
Treatments		5		
ES vs CC	(A) (1)		0.725	7.40**
Fat %	(B) (2)		1.294	13.19***
A x B	(2)		0.547	5.57
Error		35	0.098	
Total		47		

Table 20-(continued)

Source of variation		DF	Mean Square	F
Sensory score, texture				
Replications		7	0.089	1.18
Treatments		5		
ES vs CC	(A) (1)		0.013	0.18
Fat %	(B) (2)		0.182	2.40
A x B	(2)		0.007	0.10
Error		35	0.076	
Total		47		
Sensory score, tenderness				
Replications		7	0.074	1.07
Treatments		5		
ES vs CC	(A) (1)		0.270	3.89
Fat %	(B) (2)		0.433	6.23**
A x B	(2)		0.031	0.44
Error		35	0.069	
Total		47		
Sensory score, apparent degree of doneness				
Replications		7	0.207	2.13
Treatments		5		
ES vs CC	(A) (1)		0.213	2.19
Fat %	(B) (2)		1.603	16.47***
A x B	(2)		0.256	2.64
Error		35	0.097	
Total		47		
Color difference, HunterLab Spectrophotometer, cooked				
L (lightness)				
Replications		7	1.117	0.80
Treatments		5		
ES vs CC	(A) (1)		0.009	0.01
Fat %	(B) (2)		4.609	3.32*
A x B	(2)		0.699	0.50
Error		35	1.389	
Total		47		

Table 20-(concluded)

Source of variation		DF	Mean Square	F
a+ (redness)				
Replications		7	0.274	0.80
Treatments		5		
ES vs CC	(A) (1)		0.085	0.25
Fat %	(B) (2)		3.987	11.70**
A x B	(2)		0.477	1.40
Error		35	0.341	
Total		47		
b+ (yellowness)				
Replications		7	0.120	0.42
Treatments		5		
ES vs CC	(A) (1)		0.004	0.02
Fat %	(B) (2)		0.479	1.68
A x B	(2)		0.095	0.33
Error		35	0.284	
Total		47		

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

Table 21-pH and log viable counts per grams of thawed raw ground beef

Replication	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	pH					
1	5.64	5.65	5.83	5.74	5.77	5.80
2	5.46	5.67	5.83	5.74	5.75	5.74
3	5.66	5.66	5.76	5.76	5.75	5.73
4	5.56	5.55	5.68	5.73	5.72	5.74
5	5.54	5.55	5.77	5.72	5.77	5.77
6	5.57	5.73	5.75	5.72	5.78	5.75
7	5.61	5.74	5.77	5.77	5.76	5.79
8	5.60	5.78	5.74	5.75	5.77	5.74
Avg.	5.58	5.67	5.77	5.74	5.76	5.77
	Log viable counts/g at 32°C					
1	4.41	4.48	4.67	5.65	4.67	4.41
2	4.43	4.54	4.44	5.28	4.81	4.50
3	3.90	4.08	4.08	4.99	4.00	4.20
4	4.46	4.47	4.48	6.14	4.48	4.57
5	5.47	4.69	4.47	5.77	5.16	4.60
6	4.62	4.56	4.64	5.78	4.49	4.75
7	4.41	4.54	4.48	6.05	4.69	4.36
8	4.46	4.66	4.18	6.09	5.53	4.54
Avg.	4.52	4.50	4.43	5.72	4.73	4.49

Table 21-(concluded)

Replications	Treatments[a]					
	ES10	ES15	ES20	CC10	CC15	CC20
	Log viable counts/g at 25°C					
1	4.35	4.59	4.62	5.94	4.86	4.79
2	4.58	4.71	4.57	5.19	4.72	4.56
3	4.54	4.60	4.59	5.22	4.72	4.60
4	4.41	4.52	4.41	5.69	4.85	4.51
5	5.64	4.52	4.58	5.79	5.32	4.57
6	4.62	4.62	4.59	5.86	4.67	4.59
7	4.48	4.53	4.57	6.20	4.90	4.59
8	4.51	4.53	4.23	6.15	4.79	4.61
Avg.	4.64	4.58	4.52	5.76	4.85	4.60
	Log viable counts/g at 5°C					
1	4.20	4.38	4.58	5.50	4.97	4.18
2	4.41	4.56	4.45	5.60	4.60	4.45
3	4.41	4.45	4.42	5.26	4.68	4.51
4	4.48	4.54	4.43	5.72	4.61	4.65
5	4.82	4.67	4.51	4.97	4.78	4.56
6	4.47	4.41	4.32	4.81	4.53	4.54
7	4.28	4.41	4.26	5.38	4.59	4.51
8	4.28	4.46	4.26	4.89	4.72	4.56
Avg.	4.42	4.49	4.40	5.27	4.66	4.50

[a]Treatments: CC-10, 15 or 20 = Conventionally Chilled, 10, 15 or 20% fat. ES-10, 15 or 20 = Electrically Stimulated 10, 15 or 20% fat.

Table 22-Analysis of variance for pH and log of viable counts per gram of thawed raw ground beef.

Source of variation		DF	Mean Square	F
pH				
Treatments		5		
ES vs CC	(A)	(1)	0.080	32.41***
Fat %	(B)	(2)	0.041	16.61***
A x B		(2)	0.029	11.85***
Error		42		
Total		47		
Log of viable counts/g at 32°C				
Treatments		5		
ES vs CC	(A)	(1)	2.945	26.20***
Fat %	(B)	(2)	1.898	16.88***
A x B		(2)	1.511	13.44***
Error		42	0.112	
Total		47		
Log of viable counts/g at 25°C				
Treatments		5		
ES vs CC	(A)	(1)	2.891	44.98***
Fat %	(B)	(2)	1.766	27.48***
A x B		(2)	1.202	18.69***
Error		42	0.064	
Total		47		
Log of viable counts/g at 5°C				
Treatments		5		
ES vs CC	(A)	(1)	1.654	48.52***
Fat %	(B)	(2)	0.647	18.98***
A x B		(2)	0.688	20.17***
Error		42	0.034	
Total		47		

*** $P < 0.001$

Table 23-Values[a] for selected color measurements of electrically stimulated fresh raw ground beef with 10% fat (ES10) vs exposure time period.

Exposure time period[b]	Color measurements										
	% Reflectance						HunterLab				Visual color score
	474nm	525nm	571nm	$\frac{474}{525}$	$\frac{571}{525}$	(630nm-580nm)	L	a	b	a/b	
0	14.24	13.71	12.97	1.04	0.95	11.59	39.33	9.26	6.05	1.53	3.00
1	17.06	16.47	15.79	1.04	0.96	9.70	-----	----	----		3.00
2	14.65	14.05	13.35	1.04	0.95	10.18	40.78	7.33	5.26	1.37	3.25
3	17.34	16.78	16.10	1.03	0.96	9.70	42.78	6.72	5.18	1.30	3.50
4	17.11	16.57	15.97	1.03	0.96	9.13	42.40	6.44	4.99	1.29	3.50
5	16.86	16.34	15.84	1.03	0.97	8.39	42.01	5.99	4.76	1.26	3.75
6	17.04	16.49	15.98	1.03	0.97	8.39	42.22	5.94	4.74	1.25	3.75
7	9.32	8.92	8.41	1.04	0.94	8.46	32.01	7.88	6.45	1.22	3.75
8	8.94	8.51	8.06	1.05	0.95	8.42	31.44	8.12	6.47	1.26	4.00

[a]One observation.

[b]Intervals between each time period is equal to 30 min.

Table 24-Values[a] for selected color measurements of electrically stimulated fresh raw ground beef with 15% fat (ES15) vs exposure time period.

Exposure time period[b]	Color measurements										
	% Reflectance						HunterLab				Visual color score
	474nm	525nm	571nm	$\frac{474}{525}$	$\frac{571}{525}$	(630nm-580nm)	L	a	b	a/b	
0	17.67	17.27	16.09	1.02	0.93	16.16	43.83	10.70	7.56	1.42	3.00
1	18.79	18.22	17.09	1.03	0.94	15.05	45.08	9.92	6.39	1.55	3.00
2	19.48	18.94	17.85	1.03	0.94	14.11	-----	----	----	----	3.00
3	19.44	18.86	17.83	1.03	0.95	13.48	-----	----	----	----	3.50
4	19.32	18.70	17.78	1.03	0.95	13.07	45.23	8.64	5.98	1.44	3.50
5	18.08	17.38	16.41	1.04	0.94	12.89	40.92	9.56	7.24	1.32	3.75
6	20.10	19.47	18.86	1.03	0.97	10.54	45.73	6.61	5.82	1.14	3.75
7	19.86	19.29	18.42	1.03	0.95	12.42	45.84	7.89	5.99	1.32	3.75
8	19.42	18.85	18.13	1.03	0.96	13.42	45.59	8.94	7.07	1.26	4.00

[a]One observation.

[b]Intervals between each time period is equal to 30 min.

Table 25-Values[a] for selected color measurements of electrically stimulated fresh raw ground beef with 20% fat (ES20) vs exposure time period.

Exposure time period[b]	Color measurements										
	% Reflectance						HunterLab				Visual color score
	474nm	525nm	571nm	$\frac{474}{525}$	$\frac{571}{525}$	(630nm-580nm)	L	a	b	a/b	
0	21.67	21.02	19.34	1.03	0.92	17.86	46.79	9.99	7.66	1.30	3.00
1	22.27	21.57	20.11	1.03	0.93	16.00	-----	----	----		3.00
2	23.03	22.38	20.89	1.03	0.93	15.45	-----	----	----		3.00
3	23.33	22.66	21.19	1.03	0.94	15.30	-----	----	----		3.50
4	23.68	23.06	21.61	1.03	0.94	15.30	49.85	8.30	7.03	1.18	3.50
5	23.59	22.91	21.52	1.03	0.94	14.74	-----	----	----		3.50
6	23.83	22.13	21.80	1.03	0.94	14.51	-----	----	----		3.75
7	23.63	22.82	21.60	1.04	0.95	14.27	-----	----	----		3.75
8	24.03	23.28	22.04	1.03	0.95	14.24	-----	----	----		3.75

[a]One observation.

[b]Intervals between each time period is equal to 30 min.

Table 26-Values[a] for selected color measurements of conventionally chilled fresh raw ground beef with 10% fat (CC10) vs exposure time period.

Exposure time period[b]	Color measurements										
	% Reflectance						HunterLab				Visual color score
	474nm	525nm	571nm	$\frac{474}{525}$	$\frac{571}{525}$	(630nm-580nm)	L	a	b	a/b	
0	17.72	17.03	16.19	1.04	0.95	11.92	43.02	8.42	5.20	1.06	2.00
1	18.27	17.67	16.85	1.03	0.95	11.44	43.47	8.00	5.13	1.56	2.00
2	18.10	17.38	16.48	1.04	0.95	11.33	43.54	7.69	5.01	1.53	2.00
3	17.84	17.23	16.39	1.04	0.95	10.89	43.43	7.53	4.90	1.54	2.50
4	18.02	17.46	16.57	1.03	0.95	10.92	43.60	7.43	5.13	1.45	3.00
5	18.16	17.57	16.72	1.03	0.95	10.77	43.69	7.34	5.03	1.46	3.00
6	18.26	17.67	16.74	1.03	0.95	10.98	43.78	7.34	5.02	1.46	3.50
7	18.44	17.82	16.95	1.03	0.95	10.63	-----	----	----		3.75
8	18.00	17.39	16.54	1.03	0.95	10.41	40.63	7.93	5.87	1.35	3.75

[a]One observation.

[b]Intervals between each time period is equal to 30 min.

Table 27-Values[a] for selected color measurements of conventionally chilled fresh raw ground beef with 15% fat (CC15) vs exposure time period.

Exposure time period[b]	Color measurements										
	% Reflectance						HunterLab				Visual color score
	474nm	525nm	571nm	$\frac{474}{525}$	$\frac{571}{525}$	(630nm-580nm)	L	a	b	a/b	
0	19.91	19.29	17.72	1.03	0.92	16.92	46.45	9.83	7.29	1.35	2.00
1	20.25	19.61	17.88	1.03	0.91	18.51	46.86	10.95	6.99	1.57	2.00
2	20.19	19.60	18.17	1.03	0.93	16.64	46.65	10.00	6.02	1.66	2.00
3	20.52	19.86	18.31	1.03	0.92	16.55	46.82	9.85	6.63	1.49	2.50
4	20.50	19.83	18.25	1.03	0.92	16.29	46.77	9.66	6.53	1.46	2.50
5	20.56	20.05	18.37	1.02	0.92	16.32	46.90	9.51	6.77	1.46	3.00
6	18.98	18.29	17.50	1.04	0.95	10.95	44.75	6.92	5.47	1.27	3.25
7	21.41	20.91	19.40	1.02	0.93	15.29	47.78	8.72	6.70	1.30	3.25
8	22.21	21.64	20.20	1.03	0.93	15.03	48.53	8.42	6.56	1.28	3.25

[a]One observation.

[b]Intevals between each time period is equal to 30 min.

Table 28-Values[a] for selected color measurements of conventionally chilled fresh raw ground beef with 20% fat (CC20) vs exposure time period.

Exposure time period[b]	Color measurements										
	% Reflectance						HunterLab				Visual color score
	474nm	525nm	571nm	$\frac{474}{525}$	$\frac{571}{525}$	(630nm-580nm)	L	a	b	a/b	
0	20.73	20.27	19.46	1.02	0.96	13.97	47.43	8.50	7.43	1.14	3.00
1	20.16	19.73	19.15	1.02	0.97	13.49	46.98	8.47	7.56	1.12	3.00
2	21.51	21.01	20.37	1.02	0.97	13.26	48.30	8.16	7.02	1.16	3.00
3	21.90	21.46	20.74	1.02	0.97	13.51	48.66	8.18	6.99	1.17	3.00
4	21.94	21.45	20.88	1.02	0.97	12.16	48.57	7.36	6.55	1.12	3.00
5	20.60	19.96	19.27	1.03	0.97	12.73	46.90	8.06	6.51	1.14	3.25
6	21.18	20.55	19.84	1.03	0.97	10.58	47.22	6.43	5.59	1.15	3.25
7	22.89	22.34	21.58	1.02	0.97	12.55	49.28	7.42	6.57	1.13	3.25
8	22.97	22.37	21.61	1.03	0.97	12.17	49.30	7.15	6.37	1.12	3.50

[a]One observation.

[b]Intervals between each time period is equal to 30 min.

Table 29-F value attributable to fat level for selected color measurements during 4 hours of exposure (0 through 8 time periods) for raw ground beef.

Exposure time period[a]	Color measurements								
	% Reflectance		K/S value					HunterLab	
	474/525	571/525	474	525	571	474/525	571/525	L	b
0	3.25*	ns	20.41***	19.69***	16.26***	ns	6.02**	51.14***	14.69***
1	5.41**	3.60*	7.77**	10.26***	5.74**	ns	6.86**	31.24***	41.42***
2	5.88**	ns	11.48***	15.15***	8.99***	ns	5.84**	26.15***	25.26***
3	8.05**	ns	13.52***	14.47***	9.86***	ns	ns	39.52***	26.83***
4	5.24**	ns	11.70***	22.89***	13.79***	ns	6.04**	33.61***	45.42***
5	ns	ns	20.04***	18.22***	16.20***	ns	ns	29.25***	34.03***
6	ns	ns	14.91***	15.98***	11.29***	ns	6.73**	28.05***	18.04***
7	ns	ns	20.08***	20.88***	14.61***	ns	5.21**	37.14***	30.11***
8	ns	ns	23.65***	24.78***	17.94***	3.41*	3.82*	34.81***	32.43***

[a]Interval between each time period is equal to 30 min.

*P < 0.05
**P < 0.01
***P < 0.001
ns = not significant

Table 30-Mean values, standard errors and LSDs for percentage reflectance at 474nm vs exposure time period for raw ground beef.

Time period of exposure[a]		Level of fat			LSD[b]
		10	15	20	
0	Mean	16.59	18.84	20.73	1.17
	S.E.	0.41	0.41	0.41	
1	Mean	17.39	18.86	21.09	1.34
	S.E.	0.47	0.47	0.47	
2	Mean	16.72	18.72	20.75	1.34
	S.E.	0.47	0.47	0.47	
3	Mean	17.34	19.39	21.27	1.17
	S.E.	0.41	0.41	0.41	
4	Mean	16.75	19.18	21.24	1.40
	S.E.	0.49	0.49	0.49	
5	Mean	16.79	18.99	21.37	1.37
	S.E.	0.48	0.48	0.48	
6	Mean	17.21	19.63	21.57	1.37
	S.E.	0.48	0.48	0.48	
7	Mean	17.12	19.91	21.47	1.20
	S.E.	0.42	0.42	0.42	
8	Mean	17.52	19.72	22.18	1.29
	S.E.	0.45	0.45	0.45	

[a]Interval between each time period is equal to 30 min.

[b]Least significant difference at 5% level of probability.

Table 31-Mean values, standard error and LSDs for percentage reflectance at 525nm vs exposure time period for raw ground beef.

Time period of exposure[a]		Level of fat			LSD[b]
		10	15	20	
0	Mean	15.90	18.19	20.09	1.17
	S.E.	0.41	0.41	0.41	
1	Mean	16.77	18.17	20.59	1.29
	S.E.	0.45	0.45	0.45	
2	Mean	15.98	18.05	20.20	1.32
	S.E.	0.46	0.46	0.46	
3	Mean	16.65	18.71	20.79	1.12
	S.E.	0.39	0.39	0.39	
4	Mean	16.05	18.47	20.70	1.34
	S.E.	0.47	0.47	0.47	
5	Mean	16.15	18.11	20.85	1.32
	S.E.	0.46	0.46	0.46	
6	Mean	16.56	18.97	21.03	1.32
	S.E.	0.46	0.46	0.46	
7	Mean	16.43	19.21	21.41	1.37
	S.E.	0.48	0.48	0.48	
8	Mean	16.86	19.02	21.60	1.23
	S.E.	0.43	0.43	0.43	

[a]Interval between each time period is equal to 30 min.

[b]Least significant differences at 5% level of probability.

Table 32-Mean values, standard error and LSDs for percentage of reflectance at 571nm vs exposure time period for raw ground beef.

Time period of exposure[a]		Level of fat			LSD[b]
		10	15	20	
0	Mean	15.08	17.15	18.84	1.14
	S.E.	0.40	0.40	0.40	
1	Mean	16.06	17.08	19.21	1.32
	S.E.	0.46	0.46	0.46	
2	Mean	15.16	17.86	18.81	1.86
	S.E.	0.65	0.65	0.65	
3	Mean	15.87	18.32c	19.41c	1.52
	S.E.	0.53	0.53	0.53	
4	Mean	15.29	17.45	19.33	1.40
	S.E.	0.49	0.49	0.49	
5	Mean	15.43	17.36	19.48	1.37
	S.E.	0.48	0.48	0.48	
6	Mean	15.87	17.97	19.67	1.34
	S.E.	0.47	0.47	0.47	
7	Mean	15.76	18.20	19.59	1.26
	S.E.	0.44	0.44	0.44	
8	Mean	16.14	18.04	20.32	1.29
	S.E.	0.45	0.45	0.45	

[a]Interval between each time period is equal to 30 min.

[b]Least significant difference at 5% level of probability, means having the same letter (c) are not significantly different.

Table 33-Mean values, standard errors and LSDs for percentage reflectance of the difference 630nm-580nm vs exposure time period for raw ground beef

Exposure time period[b]		Treatments[a]						LSD[c]
		ES10	ES15	ES20	CC10	CC15	CC20	
0	Mean	11.60d	13.20de	14.29e	11.64d	14.79e	18.23	1.63
	S.E.	0.57	0.57	0.57	0.57	0.57	0.57	
1	Mean	10.72d	12.95f	14.06ef	11.31d	15.08e	17.72	1.40
	S.E.	0.49	0.49	0.49	0.49	0.49	0.49	
2	Mean	10.93d	12.92	14.67e	11.44d	15.01e	17.68	1.46
	S.E.	0.51	0.51	0.51	0.51	0.51	0.51	
3	Mean	10.36d	12.52	14.90e	10.81d	14.87e	17.01	1.46
	S.E.	0.51	0.51	0.51	0.51	0.51	0.51	
4	Mean	10.59f	12.46d	14.59e	11.45df	14.46e	16.85	1.57
	S.E.	0.55	0.55	0.55	0.55	0.55	0.55	
5	Mean	10.31d	11.80d	14.64e	10.91d	14.48e	15.99e	1.57
	S.E.	0.55	0.55	0.55	0.55	0.55	0.55	
6	Mean	10.11f	12.00d	14.42e	11.12df	13.99e	16.27	1.54
	S.E.	0.54	0.54	0.54	0.54	0.54	0.54	
7	Mean	9.98d	12.23f	13.59ef	10.92d	13.79e	16.42	1.52
	S.E.	0.53	0.53	0.53	0.53	0.53	0.53	
8	Mean	9.57	12.20d	13.87e	11.08d	14.04e	16.34	1.34
	S.E.	0.47	0.47	0.47	0.47	0.47	0.47	

[a]Treatments: CC10, 15, 20 = Conventionally Chilled 10, 15, 20% fat; ES10, 15, 20 = Electrically Stimulated 10, 15, 20% fat.

[b]The interval between each time period is equal to 30 min.

[c]Least significant difference at 5% level of probability; means having the same letters (d-f) are not significantly different.

Table 34-Analysis of variance for percentage reflectance for 630nm-580nm vs time exposure period for raw ground beef.

Source of variation			DF	Mean Square	F
Time 0					
Treatments			5		
ES vs CC	(A)	(1)		41.367	15.77***
Fat %	(B)	(2)		86.133	32.83***
A x B		(2)		15.357	5.85**
Error			42	2.623	
Total			47		
Time 1					
Treatments			5		
ES vs CC	(A)	(1)		54.166	27.64***
Fat %	(B)	(2)		96.814	49.41***
A x B		(2)		9.418	4.81**
Error			42	1.959	
Total			47		
Time 2					
Treatments			5		
ES vs CC	(A)	(1)		42.000	20.28***
Fat %	(B)	(2)		100.146	48.35***
A x B		(2)		6.365	3.07
Error			42	2.071	
Total			47		
Time 3					
Treatments			5		
ES vs CC	(A)	(1)		32.308	15.51**
Fat %	(B)	(2)		116.351	55.87***
A x B		(2)		4.260	2.05
Error			42	2.082	
Total			47		

Table 34-(continued)

Source of variation			DF	Mean Square	F
Time 4					
Treatments			5		
ES vs CC	(A)	(1)		35.055	14.48**
Fat %	(B)	(2)		88.425	36.52***
A x B		(2)		2.229	0.92
Error			42	2.421	
Total			47		
Time 5					
Treatments			5		
ES vs CC	(A)	(1)		28.536	11.97**
Fat %	(B)	(2)		88.845	37.28***
A x B		(2)		4.454	1.87
Error			42	2.383	
Total			47		
Time 6					
Treatments			5		
ES vs CC	(A)	(1)		31.395	13.47**
Fat %	(B)	(2)		89.587	38.43***
A x B		(2)		1.125	0.48
Error			42	2.331	
Total			47		
Time 7					
Treatments			5		
ES vs CC	(A)	(1)		37.666	17.08**
Fat %	(B)	(2)		83.443	37.83***
A x B		(2)		3.707	1.68
Error			42	2.206	
Total			47		

Table 34-(concluded)

Source of variation		DF	Mean Square	F
Time 8				
Treatments		5		
ES vs CC	(A) (1)		45.241	25.79***
Fat %	(B) (2)		92.034	52.47***
A x B	(2)		0.967	0.55
Error		42	1.754	
Total		47		

* P < 0.05

** P < 0.01

*** P < 0.001

Table 35-Mean values, standard errors and LSDs for the difference between 8 and 0 exposure time period of selected color measurements for raw ground beef.

Measurements		Treatments[a]						LSD[b]
		ES10	ES15	ES20	CC10	CC15	CC20	
%R (630nm-580nm)	Mean	-4.23g	-3.48fg	-1.85e	-0.31d	-2.33ef	-4.23g	1.34
	S.E.	0.47	0.47	0.47	0.47	0.47	0.47	
HunterLab a values	Mean	-2.84	-1.60d	-1.32d	0.36d	-0.87d	-1.54d	1.23
	S.E.	0.43	0.43	0.43	0.43	0.43	0.43	
Ratio $\frac{a}{b}$	Mean	-0.29d	-0.16de	-0.27d	-0.08e	-0.04e	-0.02e	0.14
	S.E.	0.05	0.05	0.05	0.05	0.05	0.05	
Visual color scores	Mean	1.16	0.53de	0.63d	0.31ef	0.25f	0.66d	0.26
	S.E.	0.09	0.09	0.09	0.09	0.09	0.09	

[a]Treatments: CC10, 15, 20 = Conventionally Chilled 10, 15, 20% fat. ES10, 15, 20 = Electrically Stimulated 10, 15, 20% fat.

[b]Least significant differences at the 5% level of probability. Mean values with the same letter (d-f) are not significantly different.

Table 36-Mean values, standard errors and LSDs for K/S 474nm vs exposure time period for raw ground beef.

Exposure time period[a]		Level of fat			LSD[b]
		10	15	20	
0	Mean	2.17	1.80	1.55	0.20
	S.E.	0.07	0.07	0.07	
1	Mean	1.99c	1.82c	1.55	0.23
	S.E.	0.08	0.08	0.08	
2	Mean	2.15	1.85	1.59	0.23
	S.E.	0.08	0.08	0.08	
3	Mean	2.09	1.76	1.51	0.23
	S.E.	0.08	0.08	0.08	
4	Mean	2.10	1.76c	1.50c	0.26
	S.E.	0.09	0.09	0.09	
5	Mean	2.16	1.79	1.50	0.20
	S.E.	0.07	0.07	0.07	
6	Mean	2.06	1.70c	1.48c	0.23
	S.E.	0.08	0.08	0.08	
7	Mean	2.12	1.66c	1.48c	0.20
	S.E.	0.07	0.07	0.07	
8	Mean	2.06	1.69	1.41	0.20
	S.E.	0.07	0.07	0.07	

[a]Interval between each time period is equal to 30 min.

[b]Least significant difference at the 5% level of probability. Means having the same letter (c) are not significantly different.

Table 37-Mean values, standard errors and LSDs for K/S 525nm vs exposure time period for raw ground beef.

Exposure time period[a]		Level of fat 10	15	20	LSD[b]
0	Mean	2.30	1.91	1.63	0.23
	S.E.	0.08	0.08	0.08	
1	Mean	2.08c	1.92c	1.59	0.23
	S.E.	0.08	0.08	0.08	
2	Mean	2.31	1.97	1.65	0.26
	S.E.	0.09	0.09	0.09	
3	Mean	2.18	1.86	1.59	0.23
	S.E.	0.08	0.08	0.08	
4	Mean	2.30	1.85	1.55	0.23
	S.E.	0.08	0.08	0.08	
5	Mean	2.28	1.82	1.55	0.26
	S.E.	0.09	0.09	0.09	
6	Mean	2.17	1.79	1.54	0.23
	S.E.	0.08	0.08	0.08	
7	Mean	2.25	1.75c	1.54c	0.23
	S.E.	0.08	0.08	0.08	
8	Mean	2.19	1.80	1.46	0.20
	S.E.	0.07	0.07	0.07	

[a]Interval between each time period is equal to 30 min.

[b]Least significant difference at the 5% level of probability. Means having the same letter (c) are not significantly different.

Table 38-Mean values, standard errors and LSDs for K/S 571nm vs exposure time period for raw ground beef.

Exposure time period[a]		Level of fat 10	15	20	LSD[b]
0	Mean	2.48	2.08	1.79	0.26
	S.E.	0.09	0.09	0.09	
1	Mean	2.22c	2.09c	1.79	0.26
	S.E.	0.09	0.09	0.09	
2	Mean	2.49	2.15c	1.85c	0.31
	S.E.	0.11	0.11	0.11	
3	Mean	2.33	2.03c	1.79c	0.26
	S.E.	0.09	0.09	0.09	
4	Mean	2.46	2.02c	1.79c	0.29
	S.E.	0.10	0.10	0.10	
5	Mean	2.44	2.04	1.73	0.26
	S.E.	0.09	0.09	0.09	
6	Mean	2.30	1.94c	1.71c	0.26
	S.E.	0.09	0.09	0.09	
7	Mean	2.38	1.90c	1.70c	0.26
	S.E.	0.09	0.09	0.09	
8	Mean	2.34	1.95	1.61	0.26
	S.E.	0.09	0.09	0.09	

[a]Interval between each time period is equal to 30 min.

[b]Least significant difference at the 5% level of probability. Means having the same letter (c) are not significantly different.

Table 39-Mean values, standard error and LSDs for HunterLab a value vs exposure time period for raw ground beef

Exposure time period[b]		Treatments[a]						LSD[c]
		ES10	ES15	ES20	CC10	CC15	CC20	
0	Mean	8.22e	8.68de	8.90de	8.54de	9.27d	10.30	0.94
	S.E.	0.33	0.33	0.33	0.33	0.33	0.33	
1	Mean	7.66g	8.45fg	8.96ef	8.40fg	9.72de	10.17d	1.03
	S.E.	0.36	0.36	0.36	0.36	0.36	0.36	
2	Mean	7.86f	8.40ef	9.12de	8.32ef	9.70d	10.17d	1.09
	S.E.	0.38	0.38	0.38	0.38	0.38	0.38	
3	Mean	7.21e	8.07e	9.13d	7.77e	9.22d	9.71d	0.92
	S.E.	0.32	0.32	0.32	0.32	0.32	0.32	
4	Mean	7.62g	8.16efg	9.00de	8.09fg	8.97def	9.80d	0.89
	S.E.	0.31	0.31	0.31	0.31	0.31	0.31	
5	Mean	7.34f	7.76ef	8.67de	7.66ef	8.61de	9.30d	1.14
	S.E.	0.40	0.40	0.40	0.40	0.40	0.40	
6	Mean	7.02g	7.74fg	8.44def	7.92efg	8.79de	9.31d	0.92
	S.E.	0.32	0.32	0.32	0.32	0.32	0.32	
7	Mean	7.07f	7.86ef	8.31de	7.77ef	8.63de	9.18d	0.92
	S.E.	0.32	0.32	0.32	0.32	0.32	0.32	
8	Mean	6.67	7.96d	8.32d	7.92d	8.53d	9.82	1.23
	S.E.	0.43	0.43	0.43	0.43	0.43	0.43	

[a]Treatments: CC10, 15, 20 = Conventionally Chilled 10, 15, 20% fat; ES10, 15, 20 = Electrically Stimulated 10, 15, 20% fat.

[b]Interval between each time period is equal to 30 min.

[c]Least significant difference at 5% level of probability, means having the same letters (d-g) are not significantly different.

Table 40-Mean values, standard errors and LSDs for the ratio $\frac{a}{b}$ vs exposure time period for raw ground beef.

Exposure time period[b]		Treatments[a]						LSD[c]
		ES10	ES15	ES20	CC10	CC15	CC20	
0	Mean	1.41d	1.31de	1.14e	1.44d	1.33de	1.32de	0.20
	S.E.	0.07	0.07	0.07	0.07	0.07	0.07	
1	Mean	0.37de	1.29e	1.12	1.45d	1.35de	1.30e	0.14
	S.E.	0.05	0.05	0.05	0.05	0.05	0.05	
2	Mean	1.40d	1.27d	1.11	1.38d	1.29d	1.31d	0.11
	S.E.	0.04	0.04	0.04	0.04	0.04	0.04	
3	Mean	1.32d	1.29d	1.13	1.39d	1.38d	1.29de	0.20
	S.E.	0.07	0.07	0.07	0.07	0.07	0.07	
4	Mean	1.32d	1.27d	1.13	1.38d	1.32d	1.28d	0.11
	S.E.	0.04	0.04	0.04	0.04	0.04	0.04	
5	Mean	1.24d	1.18de	1.03e	1.34d	1.19de	1.24d	0.17
	S.E.	0.06	0.06	0.06	0.06	0.06	0.06	
6	Mean	1.23de	1.20de	1.06e	1.32d	1.36d	1.25de	0.20
	S.E.	0.07	0.07	0.07	0.07	0.07	0.07	
7	Mean	1.26de	1.62de	1.09f	1.33d	1.23de	1.20ef	0.11
	S.E.	0.04	0.04	0.04	0.04	0.04	0.04	
8	Mean	1.26d	1.25d	1.05	1.33d	1.22d	1.25d	0.14
	S.E.	0.05	0.05	0.05	0.05	0.05	0.05	

[a]Treatments: CC10, 15, 20 = Conventionally Chilled 10, 15, 20% fat. ES10, 15, 20 = Electrically Stimulated 10, 15, 20% fat.

[b]The interval between each time period is equal to 30 min.

[c]Least significant difference at the 5% level of probability. Means having the same letters (d-e) are not significantly different.

Table 41-Mean values, standard error and LSDs for visual color scores vs exposure time period for raw ground beef

Exposure time period[b]		Treatments[a]						LSD[c]
		ES10	ES15	ES20	CC10	CC15	CC20	
0	Mean	3.38d	3.19def	2.94efg	3.31de	2.81fg	2.72g	0.43
	S.E.	0.15	0.15	0.15	0.15	0.15	0.15	
1	Mean	3.51d	3.28d	3.06de	3.30d	2.78e	2.69e	0.51
	S.E.	0.18	0.18	0.18	0.18	0.18	0.18	
2	Mean	3.63d	3.44de	3.06ef	3.44de	3.16ef	2.81f	0.40
	S.E.	0.14	0.14	0.14	0.14	0.14	0.14	
3	Mean	3.69d	3.53de	3.31ef	3.59de	3.31ef	3.00f	0.37
	S.E.	0.13	0.13	0.13	0.13	0.13	0.13	
4	Mean	3.69d	3.56def	3.41ef	3.66de	3.34f	3.13	0.26
	S.E.	0.09	0.09	0.09	0.09	0.09	0.09	
5	Mean	3.81d	3.56de	3.50ef	3.72de	3.47ef	3.25f	0.26
	S.E.	0.09	0.09	0.09	0.09	0.09	0.09	
6	Mean	3.94d	3.69de	3.66de	3.72d	3.66de	3.41e	0.29
	S.E.	0.10	0.10	0.10	0.10	0.10	0.10	
7	Mean	4.03d	3.78de	3.75de	3.78de	3.63ef	3.47f	0.26
	S.E.	0.09	0.09	0.09	0.09	0.09	0.09	
8	Mean	4.41	3.78d	3.88d	3.81d	3.75d	3.66d	0.26
	S.E.	0.09	0.09	0.09	0.09	0.09	0.09	

[a]Treatments: CC10, 15, 20 = Conventionally Chilled, 10, 15, 20% fat; ES10, 15, 20 = Electrically Stimulated 10, 15, 20% fat.

[b]The interval between each time period is equal to 30 min.

[c]Least significant difference at 5% level of probability, means having the same letters (d-g) are not significantly different.

ELECTRICAL STIMULATION AND HOT PROCESSING: EFFECTS ON COOKING AND SENSORY PROPERTIES, COLOR AND MICROBIAL COUNT OF GROUND BEEF WITH THREE FAT LEVELS

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Color and tenderness of meat products are quality attributes important to consumers. Research has shown that electrical stimulation and hot boning of carcasses results in improved tenderness, reduction of chilling and aging time and saves cooler space.

Cattle of U.S. Choice and U.S. Good grades with weights between 410 and 500 kg were slaughtered, and at one hour after bleeding the right side of each carcass was electrically stimulated (ES, ca 600 volts, 5 amperes) for two min at a frequency of 60 cycles per second. The left side, non-stimulated control (conventionally chilled, CC) was placed in the cooler (5° ± 2°C) for 48 hr. At two hours post mortem beef flanks were removed from ES sides and divided into fat and lean. CC sides were handled the same as the hot boned, ES sides. Six ground beef products containing approximately 10, 15 or 20% fat were formulated. The products, fresh and thawed (storage at -30°C), were evaluated for cooking and sensory properties, objective measurements, pH, microbial counts, and color stability with a model system.

After 35 min cooking at 177°C, differences in end point temperature (ca 70°C) were not practical significant. There were no significant differences between ES and CC groups or among fat levels for the rate of heat penetration from the initial temperature in the patties to 70°C. In general, differences ($P < 0.05$) between ES and CC groups or among the fat levels for percentage total, volatile and drip losses could be attributed to the 20% fat samples.

Differences ($P < 0.05$) in total moisture in raw and cooked samples were attributable to fat level. For raw samples, no differences in total

moisture were found between ES and CC groups. The ES samples usually contained less ($P < 0.05$) total moisture (cooked) than did CC samples. Raw samples in the ES groups contained more ether extract than those in the CC group. In general, an increase in mean value for percentage of ether extract from raw to cooked was observed in both ES and CC groups. The pH for ES cooked samples was lower ($P < 0.05$) than that for CC samples; fat content did not affect pH of the cooked samples. Differences ($P < 0.05$) for total, serum, and fat press fluid were attributable to fat level. There were differences ($P < 0.05$) in flavor and juiciness scores between ES and CC groups with the ES group having more intense beef flavor and being slightly juicier. Differences ($P < 0.05$) for juiciness, tenderness and apparent degree of doneness were found among the fat levels with the two higher fat levels appearing more juicy, tender, and done. Texture was not affected significantly by ES and CC groups or fat level. HunterLab L value indicated darker samples with increased fat level of the cooked samples, and the HunterLab a value indicated less redness as the fat level increased. HunterLab b value did not change with an increase in fat level of the cooked samples.

For the raw products, the ES group had lower ($P < 0.05$) pH values than did the CC group. In general, differences ($P < 0.05$) in log viable counts per gram found for both ES and CC groups and among fat levels for any of the incubation temperatures (5°, 25°, 32°C) were attributable to the CC10 samples. The log counts per gram for both ES and CC groups were lower than the proposed bacteriological standard for ground beef. At each exposure time period, the difference ($P < 0.05$) in %R for 630nm-580nm for both ES and CC groups and among the fat levels were attributable to the 20% fat samples. After 4 hours of exposure to radiant energy, the

ES10 samples changed the most. K/S ratio 571/525 indicated no differences between ES and CC groups, and little change among fat levels. K/S ratio mean values increased with increasing fat content. HunterLab a value followed the MetMb formation through 4 hours of exposure to radiant energy. There was a high correlation between HunterLab a value and %R for 630nm-580nm for each of the treatment combinations. The higher the fat level, the higher the HunterLab a value; therefore, the amount of fat present may have interfered with the measurement of redness in the raw meat.

At each exposure time period, differences ($P < 0.05$) for a/b ratio between ES and CC groups and among fat levels were attributable to the 20% fat samples. ES samples with low a/b values appeared to be more sensitive to color changes than the CC samples. The moderate correlation coefficients between visual color scores and %R for 630nm-580nm indicated that the lamb color references followed the progressive changes in color of the ground beef samples through 4 hours of exposure to radiant energy. Moderate correlation occurred between the HunterLab a value and visual color score; the 20% fat samples were scored brighter than the 15 or 10% samples.