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Effects of Cooking Method, Fat Level, and Days on Feed on the Objective and Sensory Characteristics of Restructured Steaks

Carol A. Costello
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To the Graduate Council:

I am submitting herewith a dissertation written by Carol A. Costello entitled "Effects of Cooking Method, Fat Level, and Days on Feed on the Objective and Sensory Characteristics of Restructured Steaks." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Human Ecology.

Marjorie P. Penfield, Major Professor

We have read this dissertation and recommend its acceptance:

Frances A. Draughon, Roy E. Beauchene, Nina R. Marable

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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The Graduate School

EFFECTS OF COOKING METHOD, FAT LEVEL, AND DAYS ON FEED ON THE OBJECTIVE AND SENSORY CHARACTERISTICS OF RESTRUCTURED STEAKS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

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Carol A. Costello

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ABSTRACT

Top rounds from steers fed grain 0, 28, 56, or 84 days were removed and flaked in a Urschel Comitrol containing a plate with 1.9-cm openings. Fat (beef plates approximately 55% fat) from animals fed grain was finely ground. Flaked meat and fat were mixed and formed into 227-g restructured steaks with 15%, 20%, or 25% fat. Steaks were cooked in a microwave oven on a preheated browning dish or broiled in a conventional oven to an internal temperature of 73°C $\pm$ 2°C or 73°C, respectively. Greater cooking losses were exhibited for steaks heated in a microwave oven than were found with conventional heating. Objective measurements of tenderness indicated conventionally heated steaks were more tender than microwave-heated steaks. As the level of fat increased, tenderness, as determined by objective methods, generally increased. Generally, as the number of days an animal was on grain increased, Warner-Bratzler shear values decreased. Total microbial destruction was exhibited by both cooking methods. A 10-member experienced panel evaluated the steaks for various characteristics using an unstructured, 150-mm descriptive scale. Steaks cooked in the microwave oven were less tender, had less moisture released, and appeared to be more well-done than steaks broiled in the conventional oven. As fat level increased in the steaks, tenderness, moisture released, greasiness, and acceptability also increased while off-flavor of the steaks decreased. Cooking method, fat level, or number of days on feed did

not affect acceptability as judged by a 36-member consumer panel. It appeared that the use of fat from grain-fed animals minimized tenderness, juiciness, and off-flavor problems reported to be associated with meat from grass-fed animals. This study indicated that it would be feasible to utilize meat from grass-fed animals in the formation of restructured steaks. An increase in fat level was shown to positively affect the characteristics of the steaks.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Meat from grass-fed cattle may be an alternative for consumers who are paying high prices for meat from grain-fed cattle. Meat from grass-fed cattle can be produced and sold at a lower cost, but many of the physical and sensory characteristics of the meat differ from meat produced from grain-fed cattle. The meat from grass-fed beef has been shown to be less tender, less flavorful, and less acceptable than meat from grain-fed animals (Bowling et al., 1977; Dolezal et al., 1982; Meyer et al., 1960).

Off-flavors associated with meat from grass-fed animals have been linked to constituents of the fat (Melton et al., 1982). Restructuring of meat offers an opportunity to incorporate fat from grain-fed animals, thereby minimizing the off-flavor components associated with meat and fat from grass-fed animals. Restructuring is the process by which meat that is considered to be of low value is flaked and reformed into a desirable product. Through the addition of fat or additives, meat that originally would be considered less than optimal can be restructured to yield an improved product.

Restructured products probably will be introduced to the consumer in the frozen form and microwave heating should be investigated as a potential cooking method. It is estimated that 40%-50% of American homes will have a microwave oven by 1985 (Rubbright, 1981). Microwave cooking saves time and energy but may negatively affect

some of the physical and sensory properties of the food cooked in the microwave oven. Meat cooked in a microwave oven was shown to have greater cooking losses and was scored lower in flavor than meat cooked in a conventional oven (Baldwin and Russell, 1971; Cremer, 1982; Janicki and Appledorf, 1974). Other differences that could be attributed to cooking method were found in tenderness and juiciness of the meat but results were not always conclusive (Hines et al., 1980; Korschgen et al., 1976; Voris and Van Duyne, 1979). The effects of microwave heating on the quality of restructured steaks have not been investigated.

The objectives of this study were to:

1. examine the effects that cooking method, fat level, and days an animal was on feed had on the objective and sensory characteristics of restructured steaks,
2. evaluate consumer acceptance of the restructured steaks, and
3. observe the effect of cooking method on the destruction of microorganisms present in the restructured steaks.

CHAPTER II

REVIEW OF LITERATURE

1. GRASS-FED VERSUS GRAIN-FED CATTLE

Grain prices have risen rapidly in the last decade, and as a result, so has the cost of beef. Retail beef prices increased approximately 23% from 1977 to 1978 and 24% from 1978 to 1979 (NLMB, 1980). Beef prices from 1979 to early 1983 increased only 3% but as a result of the summer drought in 1983, meat prices are expected to rise again (Wilson, 1984). Grass-fed beef may be an alternative for consumers who are paying the high prices for meat from grain-fed animals. The meat from grass-fed cattle can be produced and sold at a lower cost because of the decreased amount of grain an animal must be fed (Melton et al., 1982).

Objective and Palatability Characteristics

In most cases, the characteristics of grass-fed beef have been shown to differ from those of grain-fed beef. In general, objective measurements of tenderness indicated that meat from grass-fed animals was less tender than meat from grain-fed animals. Longissimus steaks from forage-fed steers were found to have significantly higher shear values than steaks from steers finished on grain for an additional 104 days (Schroeder et al., 1982). Similar trends were described by Bowling et al. (1977), Dolezal et al. (1982), Leander et al. (1978), and Meyer et al. (1960) for rib steaks. It generally was

found that as days an animal was on feed increased, Warner-Bratzler shear measurements decreased. The results reported by Wheeling et al. (1975) differ from those of other investigators in that no significant differences were found in shear values between rib steaks from grass-fed and grain-fed beef. Similar results with longissimus, semimembranosus, and semitendinosus steaks were reported by Crouse and Seideman (1984).

Grass-fed beef may be less tender than grain-fed beef due to a cold shortening effect that happens during the chilling of the carcass. Grass-fed beef carcasses were found to have lower subcutaneous fat thickness than did grain-fed beef (Bowling et al., 1977; Dolezal et al., 1982; Tatum et al., 1980). Bowling et al. (1977) reported significant correlations between fat thickness and muscle fiber tenderness. These results support the hypothesis that decreased tenderness may be attributed to the toughening of the muscle fibers that have undergone cold shortening.

Sensory scores for tenderness differed as to whether grain-fed beef was more tender than grass-fed beef or if no significant differences in tenderness were present. Bowling et al. (1977), Dolezal et al. (1982), Dunn (1982), Harrison et al. (1978), and Meyer et al. (1960) reported that panelists found meat from grass-fed animals to be significantly less tender than meat from grain-fed animals. Longissimus steaks from grass-fed animals also were found to be less desirable in tenderness than steaks from grain-fed animals (Schroeder et al., 1980). Other investigators however have reported that there were no differences in tenderness or tenderness desirability

between rib steaks (Chastain et al., 1982; Reagan et al., 1977; Reagan et al., 1981; Tatum et al., 1980) and semitendinosus, semimembranosus, or longissimus steaks (Crouse and Seideman, 1984) from grass-fed and grain-fed animals.

The amount of grain an animal is fed influences the concentration of some of the fatty acids that are present as well as quantity of fat. Longissimus muscles from grass-fed steers were found to have significantly less total lipids and triglycerides than longissimus muscles of feedlot steers (Miller et al., 1981). Intramuscular and subcutaneous fat also have been shown to increase as the number of days an animal remained on grain increased (Westerling and Hedrick, 1979). Unsaturated fatty acids present in intramuscular and total body fat increased as the number of days an animal was on feed increased and could be attributed to a desaturation of stearic acid seen in the fat from grain-fed animals (Schroeder et al., 1980). Other changes in individual fatty acid concentrations were an increase in C18:1 and C16:0 and a decrease in C18:0 and C18:3 in ground beef from grain-fed steers (Brown et al., 1979; Melton et al., 1982). These changes in fatty acid concentration may influence the flavor of the meat.

Flavor differences in meat from grass-fed and grain-fed animals have been reported by several investigators. Longissimus steaks (Bowling et al., 1977; Harrison et al., 1978; Meyer et al., 1960; Westerling and Hedrick, 1979; Schroeder et al., 1980) and rib steaks (Dolezal et al., 1982; Reagan et al., 1977) from grain-fed animals

were scored significantly higher for flavor than were steaks from grass-fed animals. Chastain et al. (1982) reported triangle tests in which judges were able to distinguish between rib cuts from grass-fed and grain-fed animals approximately 57% of the time and to distinguish between shoulder roasts from the different feed treatments 46% of the time. There were no significant differences when the panelists were asked to indicate which sample was more flavorful. Tatum et al. (1980) also reported that as the number of days on feed increased, flavor desirability of steaks increased. However when the investigators divided the scores into three categories (very desirable, desirable, and undesirable) they found that over 90% of the steaks evaluated from grass-fed beef were rated as desirable or very desirable.

Chen et al. (1984) investigated the effect of the addition of fat on palatability characteristics of ground beef made from grass-fed animals. The samples were formulated to contain 100% of the meat and fat from grass-fed animals, 100% of the meat and fat from grain-fed animals, or 100% of the meat from grass-fed animals with the fat source being from grain-fed animals. The ground beef samples that contained 100% of the meat and fat from grain-fed animals and ground beef samples with the meat from grass-fed animals and the fat from grain-fed animals were rated significantly higher in tenderness and flavor than the ground beef samples that contained meat and fat from grass-fed animals. These results indicated that the type of fat was the factor that contributed to the difference in tenderness and flavor of these samples.

Because of the differences in fat content between meat from grass-fed and grain-fed animals, it could be projected that moisture and juiciness also would differ between treatments. Meat from grass-fed animals was found to have a significantly higher percentage of moisture than did meat from grain-fed animals (Miller et al., 1981; Leander et al., 1978; Reagan et al., 1977; Reagan et al., 1981). Results of sensory analysis for juiciness seem to contradict the finding that meat from grass-fed animals contained more moisture than did meat from grain-fed animals. Meyer et al. (1960) and Schroeder et al. (1980) reported that longissimus steaks from grass-fed animals were scored significantly less juicy than were steaks from grain-fed animals. However, no significant differences in sensory scores for juiciness were found between feed treatments for rib steaks (Bowling et al., 1977; Chastain et al., 1982; Crouse and Seideman, 1984; Reagan et al., 1977; Reagan et al., 1981; Westerling and Hedrick, 1979). The differences in moisture scores may be related to factors other than percentage moisture, such as fat percentage and the amount of moisture that is actually bound (Pedersen, 1978).

Minimum Grain-Feeding Time for Animals

It has been shown that there are significant differences in flavor, tenderness, and juiciness between meat from grass-fed and grain-fed animals. However some investigators indicated that there is a point when palatability characteristics are considered acceptable and further grain feeding does not appreciably improve the scores for the characteristics.

Melton et al. (1982) reported that the major changes in intensity of flavor notes occurred during the first 56 days on feed. They stated that reduction of time on feed to 80-90 days would yield beef that is comparable to beef held on grain for longer time periods.

A similar conclusion was described by Dolezal et al. (1982) who indicated that steers fed 100 days on feed yielded rib steaks as palatable as did steers fed 130-230 days on feed. Tatum et al. (1980) also reported that over 90% of the steaks from cattle fed 100 days on grain were rated as "very desirable" or "desirable" for overall tenderness, flavor desirability, and overall palatability. Dunn (1982) reported that meat from cattle fed 84 days on feed was acceptable and that at 84 days cattle were considered "finished."

It is necessary to investigate the minimum number of days an animal must be fed grain to yield meat with characteristics comparable to animals fed grain for extended time periods. Additional research needs to be undertaken to determine the success of incorporating meat from various feed regimes into processed meats.

2. RESTRUCTURED MEAT PRODUCTS

Process of Restructuring

Restructuring is the process by which meat that is considered to be of low value undergoes processing to create an improved product with increased value (Huffman et al., 1984). Restructuring involves flaking the intact muscle and then reforming the product. One of the most widely used flaking machines is the Comitrol, which is

manufactured by Urschel Laboratories, Inc. Farrington (1975) described the Comitrol as a machine that is equipped with a stationary cutting head which contains a ring of blades. The meat is propelled against the blades by a high speed impeller. The resulting product is thin, individual meat flakes.

After the meat is flaked, fat or additives may be added to improve the product. This feature allows the processor to have control over shape, texture, fat, moisture, flavor, and juiciness of the meat product (Breidenstein, 1982; Mandigo, 1975). Following the addition of fat and possibly other ingredients, the meat is mixed to enhance protein extractability. The mechanical action solubilizes and extracts the proteins to the surface of the meat particle whereby the proteins on meat particles come into contact with other particles (Smith, 1982; Wiebe and Schmidt, 1982). The meat then is reformed into a desirable product and usually frozen. When cooked, the meat proteins coagulate and hold the meat particles together.

Use of Restructured Products

The first prototype flaked steak was produced at the University of Nebraska in 1969 (Mandigo, 1982); the use of restructured products has increased since that time. Restructured products have characteristics that make them highly acceptable to the meat industry, food service industry, and the consumer.

With the restructuring process, processors can upgrade meat that is of low grade into higher quality products (Anonymous, 1974).

The process of restructuring enables industry to use meat that normally would not be accepted well by the consumer and to offer a greater variety of products made from red meat. Processors also have greater control over shape, texture, fat, moisture, flavor, and juiciness of the restructured meat product than with meat from intact muscle.

Restructured products most often are purchased by the food-service industry and by the military services. A list of advantages of flaked products for the food service operator has been reported by Field (1982). The advantages include that the products are uniform in portion size, totally edible, and designed for fast, high-temperature cooking by the food service operator. A further benefit is that the products could be heated in the microwave oven if they are prebrowned. The restructured products also are uniform in appearance, texture, and fat content and with this form of control, price savings could be passed on to the consumer (NLMB, 1983).

Restructuring of meat permits the production of low-cost steaks and chops which can be seen as alternatives to intact muscle (Booren et al., 1981; NLMB, 1981). Convenience of the product must be considered as another factor that would make restructured products acceptable (NLMB, 1983). Mandigo (1982) summed it up best when he described restructured steaks as "high-value consumer cuts with intermediate price and eating quality."

Characteristics of Restructured Meat

Availability of restructured steaks for consumers is limited but increased availability is expected (Breidenstein, 1982). Huffman et al. (1984) stated that restructured products may be able to compete in the retail market because of producing lower-cost products that utilize trimmings and low-grade carcasses. At the present time there have been few reports on the evaluation of restructured products. Cross and Stanfield (1976) presented restructured steaks containing 20% or 30% fat to a consumer panel. The panel found significant differences in juiciness, ease of cutting, tenderness, and overall acceptability between the steaks with the two fat levels with the greater preference for steaks that contained 30% fat. The average score for overall acceptability indicated the panelists "would eat this if available but would not go out of their way."

A trained sensory panel evaluated restructured pork chops and boneless pork loin chops for juiciness, tenderness, flavor, color, and connective tissue (Huffman and Cordray, 1979). The restructured pork products were found to be significantly more desirable in tenderness, juiciness, amount of connective tissue, and flavor than were the boneless pork loin chops. However it should be noted that the mean scores represented only three panelists' evaluations.

Huffman et al. (1984) compared beef strip steaks and restructured steaks made from beef rounds. Hedonic evaluations of strip steaks and restructured steaks were made by panelists for the characteristics of flavor, texture, and acceptability. The panelists

found the strip steaks to be more desirable in texture than the restructured steaks but there were no significant differences in flavor desirability and overall acceptability.

Restructuring is a process that can increase the quality of some cuts of meat. These products are projected to enter the consumer market soon but little has been reported on the sensory and objective characteristics.

3. EFFECT OF FAT LEVEL ON MEAT QUALITY

The amount of fat present in meat has been shown to influence many of the objective and sensory characteristics of meat products. In general, results indicated that as the amount of fat in the meat increased, the force required to shear the samples decreased. Huffman and Powell (1970) reported that ground beef patties with 35% fat required significantly less force to shear than did patties that contained 15% or 25% fat. Shear force also was shown to be significantly less for patties that contained 19% or 24% fat than it was for patties with 14% fat (Berry and Leddy, 1984). Similar results were reported by Cross and Stanfield (1976) for beef patties that contained 20% or 30% fat and which were evaluated by panelists who cut the patties with a knife.

Evaporative losses and drip losses during cooking consist of both fat and moisture. Cross et al. (1980) reported that total cooking losses of ground beef patties were not affected by fat level; however, as the fat level increased in the patties, fat losses also increased with a concominant decrease in water loss.

Sensory panelist's evaluations of meat products have shown some differences in characteristics that could be attributed to the amount of fat present in the meat. Cross and Stanfield (1976) reported significant differences in tenderness of restructured steaks with 20% or 30% fat. Steaks that contained 30% fat had higher panel ratings than did steaks that contained 20% fat. Keeton (1983) observed similar trends but differences were not significant.

An extensive sensory texture profile analysis of ground beef patties with varying fat levels was reported by Berry and Leddy (1984). Evaluation of the first bite characteristics indicated that as the level of fat increased, samples were less cohesive, softer, and less dense. A descriptive attribute panel also found that as level of fat increased, initial and final tenderness increased.

Differences for the characteristics of juiciness and the mouthcoating effect also were evaluated by Cross et al. (1980). Ground beef patties that contained 28% fat were scored more juicy and had a greater mouthcoating effect than did patties that contained 16%, 20%, or 24% fat. Differences in juiciness also were noted between steaks that contained 20% or 24% fat. There were no significant differences in mouthcoating effect among the patties that contained 16%, 20%, or 24% fat. Berry and Leddy (1984) reported that ground beef patties with 24% fat were scored significantly more juicy than were patties with 14% or 19% fat. Mouthcoating was greater for patties with the intermediate fat level than it was for patties with the lowest and highest fat percentage.

4. MICROWAVE HEATING

The microwave oven has become a very important appliance in the United States. Microwave ovens once were considered a luxury but have become a necessity in many households (Anonymous, 1980). Microwave oven usage in American homes has grown from only 6.1% of the United States households having a microwave oven in 1978 to 32.6% of the households having at least one microwave oven in 1983 (Anonymous, 1983). Estimates of ownership for 1985 range from 40% to 50% of all homes (Anonymous, 1980; Boutin, 1978; Rubbright, 1981). It appears that microwave cooking will be used to replace some of the conventional methods of cooking.

Microwave heating is a rapid method of cooking, using energy that travels at the speed of light (Decareau, 1972). The energy is transferred to water which acts as a dipole in the food. The electrical field of the microwave oven changes direction five billion times per second with the dipoles following the electrical field (Ohlsson, 1983). The temperature of the water and the food increase rapidly resulting in direct heating inside the food. Johnson and McGinley (1981) state that the heating can be attributed to the friction of the molecules vibrating against each other. Since the food is heated in the interior, cooking in the microwave oven results in more direct internal heating than is found with conventional heating.

Microwave cooking has not been used extensively for meat or meat products. A telephone survey in the Phoenix metropolitan area

indicated that only 10% of the respondents prepared meats in the microwave oven (Gast et al., 1980). Among the 10%, 65% reported that they prepared ground beef.

Energy and Time Savings

Microwave ovens were shown to have an economic advantage when small portions of meat were cooked (Roberts and Lawrie, 1974). Microwave cooking was found to reduce cooking time and resulted in energy savings. Voris and Van Duyne (1979) reported a 39% saving of electrical energy when cooking top round roasts in a microwave oven. McNeil and Penfield (1983) reported that turkey breast roasts cooked in the microwave oven cooked significantly faster and consumed 77% less energy than did turkeys cooked conventionally. Cooking time was found to decrease 77% and 94%, respectively, when beef loaves and ground beef patties were cooked in a microwave oven (Ziprin and Carlin, 1976; Drew and Rhee, 1978).

Headley and Jacobson (1960) reported that lamb roasts cooked in the microwave oven required 13 min/lb while roasts that were cooked in the conventional oven required 52 min/lb. Similar results have been reported for rib eye steaks (Baldwin and Russell, 1971), beef and pork patties (Causey et al., 1950ab), pork loin chops (Hines et al., 1980), rib roasts (Kylen et al., 1964), and top round roasts (Voris and Van Duyne, 1979). Microwave cooking is rapid because the microwaves penetrate into the food and result in instant heating. In contrast, foods that are broiled are heated mainly by conduction as the heat is applied just to the exterior of the food.

Objective and Palatability Characteristics

Results among studies are not consistent with respect to the effect of microwave cooking on the physical and sensory characteristics of meat. Consumer dissatisfaction with ground beef patties cooked in the microwave oven most likely is attributable to lack of browning, uneven cooking, and overcooking (Starrack and Johnson, 1982).

Most investigators agreed that meat cooked in the microwave oven had significantly greater cooking losses than did meat cooked in a conventional oven. Rib eye steaks cooked in a microwave oven had 33.6% total cooking losses while steaks cooked in a conventional oven had 29.8% total cooking losses (Baldwin and Russell, 1971). Headley and Jacobson (1960) reported total cooking losses for lamb roasts cooked in the microwave oven were 43%; cooking losses for roasts cooked conventionally were 35%. Other investigators report similar results for longissimus roast (Baldwin et al., 1979), ground beef patties (Janicki and Appledorf, 1974), rib steaks (Carpenter et al., 1968), beef rib roasts (Kylen et al., 1964), and beef loaves (Ziprin and Carlin, 1976). Carpenter et al. (1968) speculated that the increased cooking losses associated with microwave heating may be attributed to internal heating and rapid denaturation that forced juices out of the meat.

Results for sensory panelist evaluation of juiciness have been found to differ among studies more frequently than have objective measures of moisture. Hines et al. (1980) found pork loin chops cooked in a microwave oven to be significantly less juicy than samples

cooked in a conventional oven. Apgar et al. (1959), Baldwin and Russell (1971), and Kylen et al. (1964) reported that the juiciness of pork roasts, rib eye steaks and beef rib roasts was scored less desirable than was desirability of juiciness for meat cooked in the conventional oven. No significant differences in juiciness that could be attributed to cooking method were found for top round roasts (Korschgen et al., 1976; Voris and Van Duyne, 1979) and longissimus roasts (Baldwin et al., 1979); no significant differences in desirability of juiciness of beef patties were found between the two cooking methods (Cremer, 1982).

Microwave heating is an extremely fast method of heating and some of the structural changes that occur in meat when it is heated in a conventional oven may not occur when food is heated in a microwave oven. Roberts and Lawrie (1974) and Hsieh et al. (1980) reported that with meat cooked in the microwave oven there is less overall myofibrilar breakage than for meat cooked in the conventional oven. This seems to conflict with the view held by Carpenter et al. (1968) that meat undergoes rapid denaturation when cooked in the microwave oven.

The structural differences between meat cooked in the microwave oven and the conventional oven indicate that most likely there would be differences in tenderness of the meat cooked by the two methods; however, objective and sensory measurements of tenderness are not conclusive. Beef rib steaks (Carpenter et al., 1968) required more force to shear when cooked in a conventional oven than

when cooked in a microwave oven. Voris and Van Duyne (1979) found beef adductor muscles cooked in a microwave oven required more force to shear than did the muscles cooked in a conventional oven. Other investigators have found no significant differences in Warner-Bratzler shear values between the two cooking methods for pork roasts (Apgar et al., 1959), rib eye steaks (Baldwin and Russell, 1971), pork loin chops (Hines et al., 1980), and beef and lamb roasts (Korschgen et al., 1976).

Pork loin chops cooked in the microwave oven were judged to be significantly less tender than were samples cooked in the conventional oven (Hines et al., 1980). Tenderness desirability also was scored significantly higher for beef rib roasts (Kylen et al., 1964), beef semitendinosus muscle (Hutton et al., 1981), and rib eye steaks (Baldwin and Russell, 1971) cooked in the conventional oven than was tenderness desirability for the samples cooked in the microwave oven. No differences in tenderness or tenderness desirability were reported for longissimus roasts (Baldwin and Russell, 1971), beef patties (Cremer, 1982), lamb roasts (Headley and Jacobson, 1960), and top round roasts (Korschgen et al., 1976; Voris and Van Duyne, 1979). These results contradict current recommendations that best selections for microwave cooking are tender cuts of meat (Johnson and McGinley, 1981).

Lorenz (1976) stated that it is conceivable for flavor differences to exist between foods cooked in a microwave oven and foods cooked in a conventional oven because of completely different

time/temperature relationships. The surface temperature of the food cooked in the microwave oven rarely exceeds 100°C and usually is much lower since the heat from the food surface radiates into the microwave oven (Decareau, 1972). The surface of the meat does not get hot enough for carbonyl-amine browning to occur, thereby yielding products that are grey in color with less flavor than samples cooked in a conventional oven (Taki, 1980).

Beef patties (Cremer, 1982; Drew and Rhee, 1978), top round roasts (Voris and Van Duyne, 1979), rib eye steaks (Baldwin and Russell, 1971), rib roasts (Kylen et al., 1964) and pork loin chops (Hines et al., 1980) cooked in a microwave oven were scored significantly lower in flavor than were the same cuts cooked in a conventional oven. Other investigators found no significant differences in the flavor of beef semitendinous muscles (Hutton et al., 1981), beef loaves (Ziprin and Carlin, 1976), and beef and pork patties (Causey et al., 1950ab; Apgar et al., 1959) between the two cooking methods.

Baldwin et al. (1979) studied the effect of microwave versus conventional cooking of beef roasts representing three feed managements. The animals were fed grain for 0, 56, or 112 days. Differences in sensory scores and shear values were associated with days on feed rather than cooking method. It also was observed that microwave cooking tended to be more sensitive to feed treatment effect than was cooking in a conventional oven.

Effect of Cooking on Microorganisms

Microwave cooking is increasing in popularity which partially can be attributed to the reduction in time required to prepare food. Because cooking time in the microwave oven is faster than cooking time in a conventional oven, concern exists as to the effectiveness of destroying microorganiams present in the food (Fung and Cunningham, 1980). The destruction of microorganisms is related to time and temperature of heating and microwave cooking needs to be evaluated in relation to the survival of microorganisms.

Ockerman et al. (1977) innoculated ground beef samples with Pseudomonas putrefaciens, Lactobacillus plantarum, and Streptococcus faecalis and cooked the samples in a conventional or microwave oven. In every case, microwave heating to the same endpoint resulted in less effective kill than did heating in a conventional oven.

These results were substaniated by Crespo and Ockerman (1977) who heated ground beef to internal temperatures of 34°, 61°, and 75°C. There were significant differences in logarithmic destruction of microorganisms that could be attributed to cooking in the microwave oven. Microwave cooking was less effective than conventional heating in killing the microorganisms in the ground beef samples; similar results were shown with pork (Ockerman et al., 1976).

The decrease in microbial destruction with microwave cooking can be explained by the exposure of the food to lethal temperatures for a shorter period of time than with conventional cooking (Ockerman, 1977). Another reason for the decrease in microbial destruction is

the temperature of the food is not uniform and the surface temperature does not exceed the internal temperature. Surface temperature of meat is very important as the majority of microorganisms are present on the exterior of meat. Fung and Cunningham (1980) concluded that microwave cooking is food-dependent, and individual foods should be investigated as to the survival of microorganisms.

The reports concerned with microwave heating of meat are inconclusive with respect to the effects on tenderness, juiciness, and flavor. It appears that differences in microwave ovens, retail cuts of meat used, and other factors considered within the individual studies contributed to differences among results.

Microwave cooking is faster and more energy efficient than conventional methods of cooking. Differences in evaluations of products can be attributed to the principles governing microwave heating. Products cooked in the microwave oven tend to be less juicy, which may be attributed to greater denaturation of proteins that forces juices out; less tender, primarily due to the fast cooking time which decreases collagen solubilization; and less flavorful, caused by a decrease in surface browning. With the advancement of newer types of microwave ovens with additional features and with consumer awareness of what are the best selections for microwave cooking many of the palatability problems may be minimized. More research with new products needs to be undertaken to examine the effects of microwaves on objective, sensory, and microbiological characteristics of restructured meat products. Level of fat, number of days an animal

was on feed, and interactions between oven and fat level also should be examined as potential sources of variations in the characteristics of restructured meat.

CHAPTER III

PROCEDURE

1. SOURCE OF MEAT

The meat used in this study was from steers that were part of an ongoing project in the Department of Food Technology and Science, The University of Tennessee, Knoxville, Tennessee, entitled "The Effect of Different Kinds of Pasture and Grain Feeding Periods on Beef Carcasses Quantitative and Qualitative Traits and Palatability Characteristics." Thirty-six Angus steers were wintered on fescue, orchard grass, and clover pasture from November 1, 1982 until August 8, 1983. At that time, nine steers were slaughtered. The remainder of the steers were placed on a whole shelled corn diet and then every 28 days, up to 84 days, one group of 9 steers was slaughtered. The animals were fed grain for 0, 28, 56, or 84 days.

Beef plates, which were the fat source, were purchased from Lay's Packing Company, Knoxville, Tennessee. The plates came from animals which were on a grain diet at least 150 days so that the added fat was from grain-fed animals.

2. PRODUCTION OF RESTRUCTURED STEAKS

The plates were boned out at the meat lab, University of Tennessee, and ground in a Biro grinder (Marablehead, Ohio) through a 1.27-cm plate. The ground plates were placed in a Denison Loxswitch

mixer (Bedford, Ohio) and mixed for 4 min (2°C). After mixing, the ground plates were spread out on freezer paper and placed in the blast freezer (-23°C) for 2 hr. The ground plates were removed from the blast freezer and ground a second time through a 0.32-cm plate. The ground plates were returned to the blast freezer for an additional hour. The plates then were flaked finely in a Fatosa Silent Cutter (Sabadell, Spain). Random samples were taken and fat content was determined in triplicate according to the Modified Babcock method (Salwin et al., 1955). The flaked plates were frozen until the following day (-23°C).

Approximately 48 hr after slaughter, top rounds were removed from hindquarters. The rounds were cut into chunks and placed in styrofoam ice chests. The meat (2°C) was transported to Travis Meat and Seafood Company, Knoxville, Tennessee, where the rounds were placed in a Urschel 2100 Comitrol (Valparaiso, Indiana) and flaked through a head with 1.89-cm openings. The flaked meat was returned to the styrofoam coolers and transported back to the meat lab. The flaked rounds (4°C) were mixed in a Denison Loxswitch mixer (Bedford, Ohio) in the cooler (2°C) for 3 min, and random samples were removed for fat determination. The fat percentage of the rounds was determined in triplicate according to the Modified Babcock method (Salwin et al., 1955).

The flaked meat was divided into three lots, and the amount of flaked plate needed to adjust the fat level to 15%, 20%, or 25% was determined with the use of a Pearson square. The flaked meat

and plate were mixed 15 min in the cooler (2°C) to aid in protein extraction and to distribute the fat throughly.

The blended meat immediately was placed in a Koppens food forming machine (Bakel, Holland) equipped with a strip-steak die. Steaks 2.54 cm thick and 227 g in weight, were formed and placed in Cryovac bags. The steaks were placed in the blast freezer (-23°C) and crust frozen (approximately 1 hr, 30 min).

The steaks were removed from the freezer and vacuum packaged using a Cryovac vacuum packaging machine (Woburn, MS). The sealed bags containing the steaks were dipped in 99°C water for 2 seconds to ensure a tight seal around the steaks. The steaks were returned to the blast freezer where they were held until cooking.

3. COOKING PROCEDURE

The experimental design for this study is found in Figure 1. Twenty-four steaks, eight of each fat level, were thawed for 16-18 hr in the cooler (2°C) prior to cooking. The restructured steaks then were cooked in a General Electric microwave oven (Model JET 880 VI, 60 Hz, 120 volts, 1.25 K.W.) or a Frigidaire conventional oven (Super Model Rse-L36, 115/230-120/240 volts, 60 cycles, 10.8 K.W.).

The steaks that were to be cooked in the microwave oven were placed on preheated browning dishes. The dishes were preheated by placing them in the microwave oven and heating for 3 min, turning the dish 180°, and heating an additional 3 min. The "high" power level was used for preheating and for cooking. Two steaks were placed

Days on grain (24)[b]	0						28						56						84					
Fat level, % (8)[b]	15		20		25		15		20		25		15		20		25		15		20		25	
Cooking method[c] (4)[b]	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C	MW	C

Figure 2--Design representing number of steaks evaluated by objective and sensory methods. (a) Entire design was replicated three times within each of the days on feed; (b) numbers in parenthesis represent the number of steaks used for each of the days on grain, fat level, or cooking method; (c) MW = microwave oven, C = conventional oven.

on the preheated browning dish and cooked for a predetermined time to yield steaks with internal temperatures of 73°C $\pm$ 2°C. It is difficult to determine exact internal temperatures of food cooked in the microwave oven; therefore, preliminary work was needed to achieve an acceptable range (Lorenz, 1976). Steaks were inverted after one-half of the cooking time lapsed. Microwave cooking times for the steaks were as follows: steaks with 15% fat heated 3 min, 10 sec on each side, steaks with 20% fat heated 2 min, 55 sec on each side, and steaks with 25% fat heated 2 min, 40 sec on each side. Upon removal of the steaks from the oven, a copper-constantan thermocouple probe was placed 3.17 cm into the middle of the steak. Maximum temperature of each steak was recorded with a Honeywell Temperature Recorder (Philadelphia, PA.).

The steaks that were cooked in the conventional oven were placed on a rack in a pan and broiled. Two steaks were placed in the oven and cooked for 6 min and 30 sec. The steaks were inverted and thermocouple probes were placed 3.17 cm into the interior of the steaks. Steaks were cooked to an internal temperature of 73°C. Total cooking time for each steak was recorded.

4. SAMPLING

After cooking and cooling the steaks to room temperature, the steaks were divided in three sections. One-inch diameter cores were removed from the first and third sections for shearing with the Warner-Bratzler attachment to the Instron (Figure 2). The meat that remained

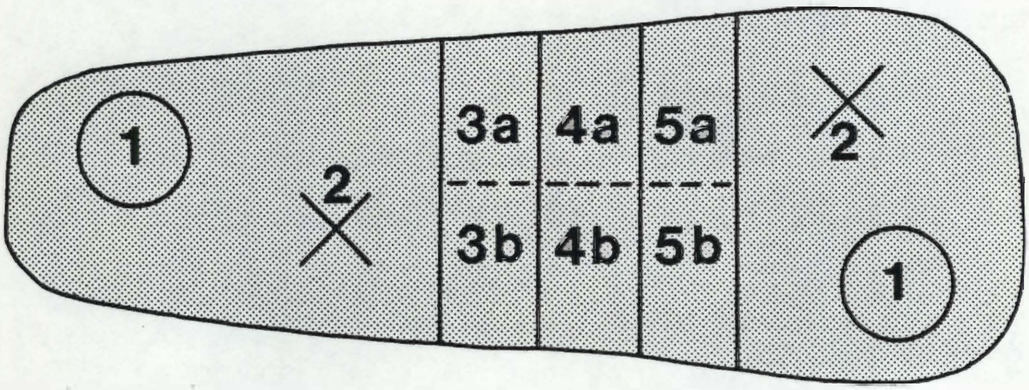

Figure 2--Sampling plan (1 = shear samples, 2 = penetration testing, 3-5 = samples for 3 sensory panelists).

from these sections was used for Instron penetration measurements (Figure 2). After removal of the cores for Warner-Bratzler measurements and completion of penetration testing, the remainder of meat was reserved for total moisture, expressible moisture testing, and percentage fat evaluation.

The middle section was divided into three 1.27-cm strips for sensory evaluation. The strips were cut in half and served to the panelists.

5. METHODS OF EVALUATION

Energy Comparison

Total wattage to preheat the conventional oven, preheat the browning dish in the microwave oven, and cook the restructured steaks in each oven were recorded from Duncan appliance meters. Kh values for the conventional oven and microwave oven were 3.6 and 0.33, respectively. Wattage and cooking power of the conventional oven were determined by the Rotating Disc Method outlined by Korschgen et al. (1980) and Leutzelschwab (1980) (Appendix A). Microwave cooking power was determined with the use of calorimetric equations for water loads (Gerling, 1978; Van Zante, 1973) (Appendix B). Relative efficiencies of the ovens were determined with the use of the following equation:

RE = cooking power (watt hr)/power input (watt hr) x 100.

The cooking power was the watt hours required to cook the restructured steaks. The power input was the watt hours required to cook the steaks and operate the ovens (Korschgen et al., 1980).

Total cooking time for each steak heated in the conventional oven was recorded. Time required for steaks to reach an internal temperature of 73°C was used as the endpoint. The time required to cook pairs of steaks in the microwave oven was determined in preliminary tests.

Cooking Losses

Total cooking losses of the steaks were determined by weighing the steaks before and after cooking. Upon removal of the steaks from the ovens, the steaks were scraped with a fork to remove coagulated protein found on the surface of the steaks. Steaks then were weighed, weight loss was determined, and percentage of total cooking losses was calculated.

Texture Evaluation

Two 1-in cylindrical cores were taken from each steak (Figure 2). The cores were taken perpendicular to the surface of the steaks and sheared in a Warner-Bratzler attachment to the Instron. Maximum force required to shear the steaks was recorded. A 50-kg load cell on the Instron was used for both shearing and penetration tests. Chart speed was 100 mm/min and crosshead speed was 50 mm/min.

A flat probe was attached to the Instron and penetrated 80% of the width of the meat samples (Bouton et al., 1971). The plunger was forced into the meat twice at the same site and work-force penetration curves obtained. Maximum force to penetrate the samples was recorded and was used as an indication of hardness. Cohesiveness

was defined as the ratio of work done during the second penetration to that of the first penetration; chewiness was defined as the product of hardness and cohesiveness (Bouton et al., 1971).

Moisture and Fat Determination

After removal of the cores for Warner-Bratzler measurements and completion of penetration tests, the remaining meat was placed in a Waring Blendor and ground. Samples were ground finely and then mixed for an additional 15 sec. Percentage moisture was determined on the steaks cooked. A 2-g ground sample was placed in preweighed filter paper and dried in the vacuum oven for 16-18 hr (AOAC, 1980). Weight loss was determined and percentage moisture was calculated.

Percentage fat also was determined on the restructured steaks. A 2-g ground sample was placed in preweighed filter paper and dried in a vacuum oven for 5 hr. The dried samples were placed in a Soxhlet fat extraction apparatus for 24 hr (AOAC, 1980). Ethyl ether (B.P. 34.5°C) was used as the solvent. Weight loss was determined and percentage fat was calculated.

Expressible moisture was determined by placing approximately 300 mg of finely ground meat on filter paper. Three sets were placed among plexiglass plates and placed in a Harco Hydraulic Press. Force applied increased from 909 kg to 2,227 kg of pressure over a time period of 5 min (NFS, 1980). Meat area and juice area were determined, and expressible moisture was calculated:

$$EMI = 1 - (\text{meat area}/\text{juice area}).$$

Microbiological Evaluation

One pair of steaks from each fat level was cooked in a microwave oven and one pair was cooked in a conventional oven. Steaks were heated according to the cooking procedure described in a previous section.

Twenty-five g of raw meat were removed from one of each pair of the steaks prior to cooking. The remainder of the steak was cooked and 25 more g were removed from each steak. Therefore, for each steak, raw and cooked samples were used for microbiological assays. All procedures that follow are discussed in Compendium of Methods for the Microbiological Examination of Foods (American Public Health Association, 1976).

The raw or cooked meat was placed in a stomacher bag that contained 225 ml of 0.1% peptone in distilled water. The contents of the bag were mixed in the stomacher for 1 min and the amounts needed for dilutions were removed. The media, temperatures, and incubation periods that were used to determine the appropriate organisms are listed in Appendix C.

Twenty-five g of raw or cooked meat were removed from the other steak in the pair. The meat was placed in selenite cysteine broth, an enrichment media for Salmonella, for 24 hr. The meat mixture then was mixed in the stomacher for 1 min and the amount needed for dilutions was removed.

After incubation periods, the number of colonies on the plates were counted. Counts were recorded as log counts. This portion of the study was done only one time.

Sensory Evaluation

Ten volunteers were recruited from the Department of Nutrition and Food Sciences and the Department of Food Technology and Science to serve on a sensory panel. The panelists had prior experience on meat sensory panels. The panelists met for an orientation session where they became familiar with the product and the scorecard (Appendix D) and developed an understanding of the terminology used (Appendix E). During this session panel members and the investigator decided upon the actual testing procedure for evaluation of the product. Further orientation sessions were held one week before each of the actual sensory evaluations. Panelists were presented with meat items that represented both extremes of the scales for evaluation of softness to tooth pressure, chewiness, greasiness, and off-flavor. The list of the foods for each characteristic is found in Appendix F.

Panelists attended one of two sensory evaluation sessions, 1:00 P.M. or 3:00 P.M. For each time period, two steaks of each fat level were cooked in the microwave oven and conventional oven. The steaks were allowed to cool to room temperature and the three middle strips were removed (1.27-cm width) and cut in half. The 10-member experienced sensory panel was presented in random order six samples representing three fat levels and two cooking methods. The samples were served on white paper plates under white light. The panel received one sample at a time with the scorecard and returned the scorecard upon completion of the evaluation of that

sample. The panel was asked to indicate the degree to which each sample exhibited each characteristic on a 150-mm unstructured scale. Characteristics evaluated were appearance, softness to tooth pressure, moisture release, chewiness, greasiness, off-flavor, and overall acceptability. The scorecard is found in Appendix D. The entire sensory evaluation procedure was replicated three times for each of the feed regimes.

Consumer Panel Evaluation

Thirty-six volunteers from The University of Tennessee, Knoxville participated in the consumer sensory panel. The panelists evaluated samples four times over a period of four months. Evaluation sessions were conducted over a four-month period to equalize the length of freezer storage time. Only meat from animals of one feeding period was evaluated at each session. For the convenience of the panelists, the restructured steak samples were presented at 10:00 A.M. or 3:00 P.M.; panelists only attended one of the sessions. Two steaks of each fat level were cooked in the microwave oven and in the conventional oven. Upon removal of the steaks from the oven, the steaks were cooled to room temeprature. The steaks were cut in 1.27-cm strips and each panelists was served one-half of the strip.

The six samples were served randomly to the panelists on white paper plates under white lights. The panelists were served one sample at a time and returned the scorecard upon completion of the evaluation of that sample.

The panelists were asked to evaluate the samples for preference on a seven-point hedonic scale and for food acceptance on a six-point scale. The Food Action scale (FACT) was used and has been reported to be a measure of the action the consumer would take (Schutz, 1965). The scorecard used for the consumer panel is found in Appendix G.

Statistical Analyses

Data were analyzed with the use of the Statistical Analysis System (SAS) developed by SAS Institute (1982). Analysis of variance (PROC ANOVA) and Tukey's test were used to determine significant differences among means for each effect. PROC GLM was used initially because of missing data; however, no differences in means and LS means were found. Additionally, core requirements made the use of PROC ANOVA desirable. The sources of variation for the sensory and objective data were cooking method, fat level, days on feed, and interactions among the variables. One-way analysis of variance and Tukey's test then were performed when significant interactions between fat and oven were found. Pearson's correlation coefficients were calculated between objective and sensory data.

CHAPTER IV

RESULTS AND DISCUSSION

Results have been divided into sections related to types of measurements or dependent variables. Within each section the effects of oven, fat level, days an animal was on feed, and significant interactions among the variables are examined. Discussion of the objective data are presented first, followed by the sensory panel data. Correlation coefficients of objective data and sensory panel data follow. A probability of 0.05 was used as the level for determining significant difference. Values reported in this section are means $\pm$ standard deviations. Analysis of variance tables can be found in Appendix H.

1. COMPOSITION OF RESTRUCTURED STEAKS

The composition of the restructured steaks is shown in Table 1. Steaks cooked in the microwave oven contained an average of 49.23% moisture and 19.70% fat (Table 1). Broiled steaks contained the same amount of moisture, 49.20%, and contained 20.72% of fat.

Steaks that were formulated to contain 15% fat had an average of 48.14% moisture and 18.14% fat after cooking (Table 1). Moisture values of 49.30% and 50.22% and fat values of 19.94% and 22.56% were found for steaks that were formulated to contain 15% and 20% fat, respectively (Table 1).

Table 1--Mean moisture and fat percentages for cooked restructured steaks with varying fat levels and produced from animals fed grain for 0, 28, 56, or 84 days[a]

	Moisture, %	Fat, %
Oven		
Microwave	49.23 ± 1.64	19.70 ± 2.54
Conventional	49.20 ± 2.23	20.72 ± 2.92
Fat Level, %		
15	48.14 ± 1.90	18.14 ± 2.13
20	49.30 ± 1.73	19.94 ± 2.36
25	50.22 ± 1.65	22.56 ± 1.81
Number of days on grain		
0	47.99 ± 1.29	18.86 ± 2.44
28	48.94 ± 2.26	20.70 ± 2.83
56	49.82 ± 1.88	20.04 ± 2.81
84	50.12 ± 1.56	21.24 ± 2.52

[a]Means ± SD for both cooking methods, all fat levels, all days on feed, and three replications.

Moisture values for steaks produced from animals on the different feed regimes ranged from 48% to 50% (Table 1). Fat values ranged from 19% to 21% (Table 1).

2. TIME AND ENERGY USAGE

Cooking method significantly affected cooking times and energy requirements for preparation of the restructured steaks. Steaks heated in the microwave oven required an average of 5.8 min to reach an internal temperature of 73°C $\pm$ 2°C while steaks broiled in the conventional oven required 13.7 min to reach an internal temperature of 73°C (Table 2). Total cooking time, which included the time to preheat the browning dish in the microwave oven or time to preheat the conventional oven, also was significantly greater for steaks broiled in the conventional oven than it was for steaks heated in the microwave oven (Table 2). A significant interaction for fat X oven was noted for cooking time both with and without preheating (Table 3), indicating that the main effect of oven is related to the main effect of fat level of the steaks. As the level of fat increased in steaks cooked in the microwave oven, no differences in cooking time were noted. There were no differences in cooking times for conventionally cooked steaks that contained 20% or 25% fat. Cooking times usually are less for foods cooked in the microwave oven or for foods with higher fat levels (Decareau, 1972).

Previous investigators have reported that microwave heating required significantly less time than did conventional heating.

Table 2--Cooking times and energy measurements for restructured steaks cooked in microwave and conventional ovens[a,b]

Variable	Oven: Microwave	Oven: Conventional
Cooking time, without preheating, min	5.8x $\pm$ 0.4	13.5y $\pm$ 1.9
Cooking time, with preheating, min	11.8x $\pm$ 0.4	18.5y $\pm$ 1.9
Energy consumed without preheating,wh	122.6x $\pm$ 8.7	604.7y $\pm$ 84.7
Energy consumed with preheating, wh	248.6x $\pm$ 8.7	822.7y $\pm$ 84.7

[a]Means $\pm$ SD representing all fat levels, all days on feed, and three replications.

[b]Means within a row followed by different letters differ at $P<0.05$.

Table 3--Cooking times and energy measurements for steaks cooked by two cooking methods and containing three fat levels[a,b],

	Oven					
	Microwave			Conventional		
	Fat level, %			Fat level, %		
Variable	15	20	25	15	20	25
Time, without preheating, min	6.3r ± 0.0	5.8r ± 0.0	5.3r ± 0.0	14.5v ± 1.9	13.2w ± 1.7	12.8w ± 1.6
Time, with preheating, min	12.3r ± 0.0	11.8r ± 0.0	11.3r ± 0.0	19.5v ± 1.9	18.2w ± 1.7	17.8w ± 1.6
Energy consumed without preheating, wh	132.2r ± 3.4	121.6r ± 4.4	113.8r ± 5.2	649.2s ±74.5	595.0t ±69.0	570.0t ±90.5
Energy consumed with preheating, wh	258.2r ± 3.4	247.6r ± 4.4	239.8r ± 5.2	867.2s ±74.5	813.0t ±69.0	788.0t ±90.5

[a]Means ± SD representing all days on feed.

[b]Means within rows followed by different letters differ at $P<0.05$.

Ziprin and Carlin (1976) reported a 77% decrease in cooking time for beef loaves cooked in a microwave oven than needed for loaves cooked in a conventional oven. Results reported by Voris and Van Duyne (1979) and Drew and Rhee (1978) indicated 42% savings in cooking time for top round roasts and 94% savings for ground beef patties heated in the microwave oven. Similar results have been reported for beef and pork patties (Causey et al., 1950ab), lamb roasts (Headley and Jacobson, 1960), pork loin chops (Hines et al., 1980), and beef roasts (Kylen et al., 1964). Microwave cooking is rapid because the microwaves penetrate into the food and heat instantly. Conventional ovens heat primarily by conduction, a slower process.

Total energy consumed was significantly greater in the conventional oven than in the microwave oven (Table 2). Drew and Rhee (1978) reported an energy savings of 45% when ground beef patties were cooked in the microwave oven. An energy savings of 39% was found for top round roasts cooked in the microwave oven (Voris and Van Duyne, 1979).

There also was a significant interaction for fat X oven for energy consumed with and without preheating (Table 3). In general, there was a reduction in energy consumed as the level of fat in the steaks increased; the decrease was significant with conventional heating but not with microwave heating. This may be attributed to the large energy consumption values of the broiled steaks or the fact that fat level does not affect energy consumed by steaks heated in the microwave oven. With the higher fat levels, broiling, which

relies mainly on conduction, may occur at a faster rate as the heat is transferred more rapidly throughout the meat than in meat with lower fat level.

The cooking power and relative efficiency of the microwave oven were 44.6 ± 4.9 kh and 36.3 ± 2.4%, respectively. Cooking power and relative efficiency for the conventional oven are not reported. Use of a constant rate of energy consumption value for the conventional oven resulted in negative cooking power values for some cooking periods. This suggests that energy available to operate was not constant. Therefore, rate of energy consumption should have been calculated before each cooking period. This conflicts with instructions reported by Luetzelschwab (1980) for calculation of one constant value for rate of energy consumption. In most cases, relative efficiency of the microwave oven has been reported to be greater than has the relative efficiency of the conventional oven.

Fat level of the steaks influenced cooking time and total cooking time. Cooking times were greater for steaks that contained 15% fat than they were for steaks with 20% or 25% fat (Table 4). The interaction of fat and oven with respect to cooking times was previously discussed. Berry and Leddy (1984) and Cross et al. (1980), in studies with ground beef patties of varying fat levels, reported a decrease in cooking time needed for patties with the higher fat levels so that the same degree of doneness would be achieved.

Table 4--Cooking times and energy measurements for restructured steaks of varying fat levels[a,b]

Variable	Fat level, %		
	15	20	25
Cooking time, without preheating, min	10.4x ± 4.3	9.5y ± 3.9	9.0y ± 3.9
Cooking time, with preheating, min	15.9x ± 3.8	15.0y ± 3.4	14.6y ± 3.4
Energy consumed without preheating, wh	390.7x ± 265.1	358.3y ± 242.9	346.7y ± 238.2
Energy consumed with preheating, wh	562.7x ± 310.6	530.3y ± 288.3	519.7y ± 282.9

[a]Means ± SD representing both cooking methods, all days on feed, and three replications.

[b]Means within a row followed by different letters differ at $P<0.05$.

Similar results with beef steaks of varying marbling amounts were reported by Cross (1977). Fat has been shown to heat much faster than water. The specific heat for water is 1.0 whereas the specific heat for fat is 0.5. Therefore, foods with high fat levels will heat much faster than foods with lower fat levels (Decareau, 1972).

Total energy consumed was significantly greater for steaks that contained 15% fat than it was for steaks that contained 20% or 25% fat (Table 4). These results reflect the cooking times of the steaks with the varying fat levels.

3. EFFECT OF COOKING METHOD ON COOKING LOSSES AND OBJECTIVE MEASURES OF TEXTURE

There was a significant difference in total cooking losses that could be attributed to cooking method. Steaks cooked in the microwave oven had approximately 36% total cooking losses while steaks that were cooked in the conventional oven had about 31% total cooking losses (Table 5). The main effect of oven may be related to fat level. Cooking losses for steaks cooked in the microwave remained approximately the same as the level of fat increased; however, there was an increase in total cooking losses for broiled steaks as the level of fat in the steaks increased (Table 6). The level of fat did not influence cooking losses for steaks heated in the microwave oven. Greater overall denaturation of the proteins present with microwave heating may force the juices

Table 5--Effects of cooking method on objective measurements of restructured steaks[a,b]

	Oven	
	Microwave	Conventional
Total cooking losses, %	36.19x ± 2.68	30.97y ± 3.94
Expressible moisture values	0.54x ± 0.08	0.52x ± 0.08
Warner-Bratzler shear values, kg	2.23x ± 0.92	2.48y ± 1.15
Penetration hardness, kg	1.52x ± 0.38	1.32y ± 0.35
Penetration cohesiveness	0.37x ± 0.11	0.35y ± 0.11
Penetration chewiness, kg	56.19x ± 20.62	46.45y ± 19.57

[a]Means ± SD representing all fat levels, all days on feed, and three replications.

[b]Means within a row followed by different letters differ at $P<0.05$.

Table 6--Means for steaks cooked by two cooking methods and containing three fat levels for objective measurements[a,b]

	Oven					
	Microwave			Conventional		
	Fat level, %			Fat level, %		
Variable	15	20	25	15	20	25
Cooking losses, %	35.96r $\pm$ 3.12	36.28r $\pm$ 2.49	36.32r $\pm$ 2.41	29.83s $\pm$ 4.08	30.52s $\pm$ 3.27	32.57t $\pm$ 3.98
Penetration hardness, kg	1.80r $\pm$ 0.35	1.50s $\pm$ 0.33	1.26t $\pm$ 0.25	1.53s $\pm$ 0.35	1.27t $\pm$ 0.29	1.15t $\pm$ 0.30

[a]Means $\pm$ SD representing all days on feed.

[b]Means within row followed by different letters differ at $P<0.05$.

out to a greater extent than with conventional heating so that the level of fat had no observable effect.

Significant differences in total cooking losses due to methods of heating have been reported extensively by other investigators. Rib eye steaks cooked in a microwave oven were reported to have had 33.6% total cooking losses while steaks cooked in a conventional oven had 29.8% total cooking losses (Baldwin and Russell, 1971). Total cooking losses for lamb roasts cooked in the microwave oven were 43%; cooking losses for roasts cooked in a conventional oven were 35% (Headley and Jacobson, 1960). Janicki and Appledorf (1974) reported a 40% total cooking loss for ground beef patties cooked in the microwave oven compared to 33% total cooking losses for broiled patties. Differences in cooking losses were attributed to moisture and fat losses upon cooking in the microwave oven.

In contrast, Hines et al. (1980) reported that broiled pork loin chops had 38.0% total cooking losses while microwave-heated chops had 28.3% total cooking losses. Drip losses for both cooking methods were similar but evaporative losses were much greater for chops that were broiled. Voris and Van Duyne (1979) found no differences in total cooking losses between cooking methods; but did report differences in drip losses. Top round roasts heated by both methods had approximately 26% total cooking losses but roasts heated in the microwave oven had 9.9% drip losses compared to 7.6% drip losses for roasted top rounds. There were no significant differences in expressible moisture values that could be attributed to cooking method (Table 5).

The restructured steaks cooked in the conventional oven required significantly more force to shear than did steaks cooked in the microwave oven (Table 5). An average maximum force of 2.48 kg versus 2.23 kg was needed to shear samples cooked in the conventional oven and microwave oven, respectively. Conversely, more force was required to penetrate microwave-heated steaks with a flat probe (penetration hardness) than was required for steaks cooked in the conventional oven (Table 5). A significant interaction between oven and fat also was found for penetration hardness (Table 6). The effect of fat in decreasing penetration hardness values was greater in microwave-heated steaks than with conventionally heated steaks (Table 6). Cohesiveness and chewiness were greater for microwave-heated steaks than for conventionally heated steaks (Table 5).

Objective indicators of tenderness have been found to differ among studies and among cuts of meat. Carpenter et al. (1968) reported more force was required to shear rib steaks cooked in the conventional oven than was required for steaks cooked in the microwave oven while results for adductor muscles were in reverse. Many researchers have found no significant differences in force required to shear meat heated by the two cooking methods (Apgar et al., 1959; Baldwin and Russell, 1971; Berry and Leddy, 1984; Cremer, 1982; Hines et al., 1980; Korschgen et al., 1976).

Warner-Bratzler shear values, penetration hardness, cohesiveness, and chewiness values all are considered objective indications of meat tenderness. Warner-Bratzler values indicate force required to

cut through a sample while penetration hardness values indicate force to compact and penetrate a sample and have been correlated with initial impression of tenderness (Bouton et al., 1971). Chewiness values have been correlated with residual tenderness and all penetration values have been correlated with hedonic tenderness scores (Bouton et al., 1971). All textural parameters evaluated in this study are measures of tenderness; however, they do not represent the same component of texture.

4. EFFECT OF FAT LEVEL ON COOKING LOSSES AND OBJECTIVE EVALUATION OF TEXTURE

Differences in objective measurements also were found for steaks with varying fat levels. When fat was considered as an independent effect, steaks that contained 25% fat had significantly greater cooking losses than did steaks that contained 15% or 20% fat (Table 7). Steaks with 25% fat lost approximately 34% of their weight during cooking while steaks with 15% or 20% fat lost approximately 33% of their weight. The interaction between fat and oven was previously discussed. Cross et al. (1980) reported that there were no significant differences in total cooking losses for ground beef patties with 16%, 20%, 24%, or 28% fat; however, as the level of fat increased in the patties, fat losses increased while water losses decreased. Drake et al. (1975) described a significant increase in cooking losses that was due to the amount of fat present in ground beef patties. Cooking losses increased as the

Table 7--Effects of fat level on objective measurements of restructured steaks[a,b]

	Fat level, %		
	15	20	25
Total cooking losses, %	32.90x ± 4.75	33.40x ± 4.09	34.44y ± 3.78
Expressible moisture values	0.52x ± 0.07	0.52x ± 0.07	0.55x ± 0.09
Warner-Bratzler shear values, kg	2.51x ± 1.01	2.28x ± 0.92	2.27x ± 1.18
Penetration hardness, kg	1.67x ± 0.37	1.39y ± 0.33	1.20z ± 0.28
Penetration cohesiveness	0.34x ± 0.11	0.35xy ± 0.09	0.38y ± 0.13
Penetration chewiness, kg	58.02x ± 21.98	50.05y ± 18.80	45.99y ± 19.38

[a]Means ± SD representing both cooking methods, all days on feed, and three replications.

[b]Means within a row followed by different letters differ at $P<0.05$.

amount of fat increased for patties that contained 15% and 20% fat and for patties that contained 20% and 25% fat. Differences in total cooking losses were attributed to fat loss rather than moisture loss. In the present study, total cooking losses were calculated; fat and moisture losses were not considered separately.

No significant differences were noted for expressible moisture values among the fat levels (Table 7). Expressible moisture values as calculated for this study are indications of free moisture present in samples; larger values indicate more free moisture.

No significant differences in Warner-Bratzler shear values were noted that could be attributed to fat level (Table 7). Force required to penetrate the steaks decreased as the amount of fat increased. The steaks with the higher fat levels were easier to penetrate with a flat probe than were steaks that contained the lower fat percentages. Steaks with the lower fat content had greater concentration of lean muscle that coagulated upon heating. As meat is heated, the muscle fibers toughen. With fewer muscle fibers, the impact of toughening will be smaller. The interaction of fat and oven with respect to penetration hardness was discussed previously.

Steaks that contained 15% fat were less cohesive but had greater chewiness values than did steaks with 15% fat. Additionally, steaks with 15% had greater chewiness values than did steaks with 20% fat. Bouton et al. (1971) reported a significant correlation between chewiness and residual impression of tenderness as determined by a sensory panel.

5. EFFECT OF DAYS ON FEED ON COOKING LOSSES AND OBJECTIVE MEASURES OF TEXTURE

The data illustrating the effects of days on feed on the objective characteristics of restructured steaks are presented in Table 8. Steaks from animals that were fed grain for 84 days had significantly greater total cooking losses than did the steaks from animals fed grain 0, 28, or 56 days. Steaks from animals fed grain 56 days had significantly lower total cooking losses than did steaks from animals on the other feed treatments. Results reported by Baldwin et al. (1979), Bowling et al. (1977), and Meyer et al. (1960) suggested that longissimus muscles from grain-fed animals had greater total cooking losses than did meat from grass-fed animals, however, differences were not significant.

Force required to shear steaks decreased as the number of days an animal was on grain increased from 0 to 28 days and from 28 to 56 days (Table 8). Meat from animals fed grain for 84 days required significantly more force to shear than did meat from animals fed grain for 56 days. Results discussed by other investigators indicated that thinner subcutaneous fat layers are present in grass-fed animals which may allow cold shortening to occur (Bowling et al., 1977; Dolezal et al., 1982; Schroeder et al., 1980). The effect of cold shortening has been shown to be a toughening of muscle fibers.

No significant differences among penetration hardness and cohesiveness values and expressible moisture values were attributable

Table 8--Effect of days on feed on objective characteristics of restructured steaks[a,b]

	Days on feed			
	0	28	56	84
Total cooking losses, %	33.04x ± 3.81	32.70x ± 3.43	31.45y ± 3.64	37.14z ± 3.91
Expressible moisture values	0.52x ± 0.06	0.49x ± 0.06	0.58x ± 0.06	0.52x ± 0.09
Warner-Bratzler shear values, kg	2.61x ± 1.37	2.34y ± 0.84	2.10z ± 0.84	2.36y ± 1.00
Penetration hardness, kg	1.39xy ± 0.40	1.46xy ± 0.37	1.33x ± 0.39	1.49z ± 0.34
Penetration cohesiveness	0.35x ± 0.09	0.36x ± 0.09	0.36x ± 0.11	0.36x ± 0.14
Penetration chewiness, kg	49.15x ± 19.80	52.79xy ± 18.86	48.84x ± 20.90	54.24y ± 22.57

[a]Means ± SD for both cooking methods, all fat levels, and three replications.

[b]Means within a row followed by different letters differ at $P<0.05$.

to the number of days an animal was on feed (Table 8). Steaks produced from animals fed grain 84 days had greater chewiness values than did steaks from animals on grain for 0 or 56 days. These results may reflect greater total cooking losses for steaks from animals fed grain 84 days than for steaks from the other feed regimes.

6. MICROBIAL EVALUATION

Microwave heating has been shown to be less effective in the destruction of innoculated microorganisms than heating in a conventional oven (Ockerman et al., 1977). Microwave cooking usually is much faster than is conventional heating thereby exposing the microorganisms to a lethal temperature for a shorter time period than that required for heating in a conventional oven.

Results in this study indicated that heating the restructured steaks to an internal temperature of 73°C $\pm$ 2°C destroyed the microorganisms regardless of cooking method. Microorganisms found on the raw steaks were completely destroyed after the steaks were cooked. Fung and Cunningham (1980) postulated that heat produced in microwave cooking will kill the microorganiams present in the food if size and type of food are considered when determining cooking time. It should be noted that the raw samples were not innoculated with microorganisms and the microbial counts were all low and in the acceptable range except for coliforms and staphylococci (Appendix H). Coliform counts in steaks from animals fed grain 56 or 84 days were higher than the standard for ground beef (Ayres et al., 1980). No growth of Salmonella or Lactobacillus was present in any of the steaks.

7. EFFECT OF COOKING METHOD ON SENSORY CHARACTERISTICS

The 10-member sensory panel found significant differences in the characteristics of the restructured steaks that could be attributed to cooking method. Steaks cooked in the microwave oven appeared to be more well-done than did steaks cooked in the conventional oven (Table 9). A significant interaction was noted between oven and fat. As shown in Table 10, steaks cooked in the microwave oven and with 25% fat were scored less well-done than steaks that contained 15% fat; fat level of steaks cooked in the conventional oven did not affect appearance.

The difference in appearance may be due to differences in end-point temperatures for steaks cooked in the microwave oven or in the mode of heat penetration for the two ovens. When foods are cooked in the microwave oven, heating occurs simultaneously throughout the internal portions of the foods. Microwaves penetrate the surface of the food, heating the internal portion as quickly as the exterior of the food. Foods that are broiled are heated mainly by conduction as the heat is applied just to the exterior of the foods resulting in slower heat penetration than that which occurs in the microwave oven.

Steaks cooked in the microwave oven were scored by the sensory panel to be harder and to yield less readily than were steaks cooked in the conventional oven (Table 9). These results concur with penetration values for the steaks heated by the two cooking methods.

Table 9--Effects of cooking method on the sensory characteristics of restructured steaks[a,b,c]

Characteristic[d]	Oven	
	Microwave	Conventional
Appearance	101.9x ± 27.1	65.7y ± 32.8
Softness	52.8x ± 30.5	41.9y ± 27.4
Chewiness	78.2x ± 29.5	65.0y ± 26.6
Moisture release	53.3x ± 35.7	73.4y ± 37.3
Greasiness	56.4x ± 31.4	58.0x ± 30.5
Off-flavor	45.2x ± 35.4	42.6x ± 35.3
Acceptability	80.9x ± 31.0	86.7y ± 32.0

[a]Means ± SD representing all fat levels, all days on feed, and three replications.

[b]Means in a row followed by different letters differ at $P<0.05$.

[c]Number of judges = 10.

[d]1 = rare, very soft, yields readily, slight, not at all difficult, no off-flavor, not acceptable; 150 = well-done, very hard, highly resistant, great, very difficult, extreme off-flavor, extremely acceptable.

Table 10--Means for steaks cooked by two cooking methods and containing three fat levels for sensory evaluation scores[a,b]

Characteristic[d]	Oven					
	Microwave			Conventional		
	Fat level, %			Fat level, %		
	15	20	25	15	20	25
Appearance	109.0r ± 23.0	103.3rs ± 26.9	93.5s ± 28.9	66.4t ± 33.9	64.4t ± 30.8	66.4t ± 33.8
Chewiness	62.6r ± 26.1	73.1s ± 28.1	79.5st ± 31.8	83.2st ± 25.4	84.8t ± 27.1	87.1t ± 27.4
Moisture	36.8r ± 25.3	47.4r ± 30.3	75.8st ± 38.3	62.9v ± 36.4	71.4sv ± 37.8	85.8t ± 34.2
Acceptability	68.9r ± 29.7	82.2st ± 29.8	91.8st ± 29.2	81.3s ± 33.1	85.7st ± 33.3	93.0t ± 28.5

[a]Means ± SD representing all days on feed.

[b]Means within rows followed by different letters differ at $P<0.05$.

[c]Number of judges = 10.

[d]1 = rare, yields readily, slight, not acceptable; 150 = well-done, highly resistant, great, extremely acceptable.

A significant interaction for fat X oven indicated that as the level of fat increased in steaks cooked in the microwave oven, chewiness decreased. No significant differences were found for conventionally broiled steaks with varying fat levels (Table 10).

Sensory data reported by other investigators indicated that samples cooked in the microwave oven were scored less tender or less desirable in tenderness than meat cooked in a conventional oven (Baldwin and Russell, 1971; Berry and Leddy, 1984; Hines et al., 1980; Hutton et al., 1981; Kylen et al., 1964). It should be mentioned that the above studies were performed on intact muscles and not flaked and formed products. The similarities of the effects of microwave heating on texture of intact muscle and restructured products may reflect similarities in texture. One of the goals in the formation of restructured products is that the texture will be similar to that of intact muscle.

The data in Table 9 indicate that greater moisture was released from steaks cooked in the conventional oven than was released for steaks cooked in the microwave oven. A significant interaction was found for moisture release between fat level and oven. Moisture release significantly increased as the level of fat increased for steaks cooked in the conventional oven; no differences were noted for microwave-heated steaks that contained 15% or 20% fat.

Beef semitendinosus roasts (Hutton et al., 1981) and ground beef patties (Berry and Leddy, 1984) cooked in a microwave oven

were significantly less juicy than were samples cooked in a conventional oven; however, other investigators found no significant differences in juiciness of roasts (Baldwin et al., 1979), beef patties (Cremer, 1982), and top round roasts (Voris and Van Duyne, 1979) heated by both methods.

Differences between results of this study and other studies reported may be related to total cooking losses of the steaks or appearance of the steaks. The panelists were asked to evaluate characteristics separately; however, perceived doneness of the samples may have influenced the evaluation of moisture release.

Method of cooking had no effect on greasiness and off-flavor of the restructured steaks (Table 9). However, acceptability of the steaks did differ with cooking method. The experienced sensory panel scored steaks cooked in the conventional oven to be more acceptable than were steaks cooked in the microwave oven (Table 9). Differences in acceptability may reflect sensory scores that indicated steaks cooked in the microwave oven were more well-done, harder, tougher to chew, and released less moisture than did steaks cooked in the conventional oven. A significant interaction for oven X fat indicated that as the level of fat in the microwave-heated steaks increased, acceptability also increased (Table 10). Differences in acceptability for steaks heated in the conventional oven were found only between steaks with 15% fat and 25% fat. The difference in acceptability attributed to cooking method decreased as the level of fat increased.

8. EFFECT OF FAT LEVEL ON SENSORY CHARACTERISTICS

The level of fat from grain-fed animals that was incorporated into the restructured steaks significantly affected some of the sensory characteristics. Steaks that contained 15% fat were scored more well-done than were steaks that contained 25% fat (Table 11). Cross (1977) reported no difference in apparent degree of doneness for beef steaks with varying marbling amounts. The significant interaction between oven and fat was discussed previously.

Softness increased and chewiness decreased as the level of fat in the steaks increased (Table 11). Steaks that contained 20% or 25% fat were scored softer and yielded more readily than did steaks that contained 15% fat. The effect of fat on chewiness was related to cooking method and discussed previously. The differences in softness and chewiness may be related to the lesser number of coagulated muscle fibers present in the cooked steaks with the higher fat percentages. Berry and Leddy (1984) discussed similar results with ground beef patties. Initial and final tenderness significantly increased as the amount of fat increased from 14% to 19% to 24%. Evaluation by a texture profile panel indicated that tenderness differences were attributed to less hardness, density, and cohesiveness during initial biting. Cross and Stanfield (1976) reported significant differences in ease of cutting and tenderness of restructured steaks with 20% or 30% fat. Steaks that contained 30% fat had higher panel ratings than did steaks that contained 20% fat. Keeton (1983) observed similar but non-significant trends.

Table 11--Effect of fat level on the sensory characteristics of restructured steaks[a,b,c]

Characteristic[d]	Fat level, %		
	15	20	25
Appearance	87.6x ± 35.9	83.9xy ± 34.8	79.9y ± 34.2
Softness	54.8x ± 30.0	46.2y ± 28.5	41.1y ± 28.3
Chewiness	77.1x ± 27.7	71.0y ± 28.1	66.7y ± 29.9
Moisture release	49.8x ± 33.9	59.4y ± 36.2	80.8z ± 36.6
Greasiness	51.7x ± 28.8	56.6xy ± 30.6	63.2y ± 32.3
Off-flavor	52.8x ± 40.2	43.1y ± 33.8	35.9z ± 29.5
Acceptability	75.0x ± 32.0	84.0y ± 31.6	92.4z ± 28.8

[a]Means ± SD representing both cooking methods, all days on feed, and three replications.

[b]Means in a row followed by different letters differ at $P<0.05$.

[c]Number of judges = 10.

[d]1 = rare, very soft, yields readily, slight, not at all difficult, no off-flavor, not acceptable; 150 = well-done, very hard, highly resistant, great, very difficult, extreme off-flavor, extremely acceptable.

The amount of moisture released increased as the percentage of fat increased in the steaks. In general, increasing fat levels resulted in an increase in moisture release as shown in Tables 10 and 11. Steaks that contained 25% fat released more moisture than did steaks with 15% or 20% fat. Also, steaks that contained 20% fat released more moisture than did steaks that contained 15% fat. Similar results reported by Cross et al. (1980) indicated that ground beef patties that contained 28% fat were more juicy than were patties that contained 16%, 20%, or 24% fat. Berry and Leddy (1984) stated that a texture profile panel scored ground beef patties that contained 24% fat significantly more juicy than patties that contained 14% or 19% fat.

Steaks with 25% fat were scored significantly more greasy than were steaks with 15% fat (Table 11). Results from this study concur with results reported by Cross et al. (1980) in that ground beef patties that contained 28% fat had greater mouthcoating effect than did patties that contained 16%, 20%, or 24% fat. There were no significant differences among the patties that contained 16%, 20%, or 24% fat. Berry and Leddy (1984) reported that ground beef patties with 19% fat had greater mouthcoating than did patties that contained 14% or 24% fat.

There was a decrease in the off-flavors associated with the steaks as the amount of fat increased (Table 11). With an increase in fat, the proportion of lean meat and fat from grass-fed animals decreased; this decrease allowed for a dilution of compounds responsible

for off-flavors that may be associated with lean meat and fat from animals fed limited grain.

In general, acceptability, as determined by the experienced sensory panel, increased as the level of fat increased (Table 11). The least preferred steaks contained 15% fat and were cooked in the microwave oven (Table 10). All steaks were scored in the acceptable range. The significant interaction between fat and oven was discussed previously.

9. EFFECT OF DAYS ON FEED ON SENSORY CHARACTERISTICS

There were no significant differences in any of the sensory characteristics except appearance that could be attributed to the days an animal was on grain (Table 12). These results contradict results reported by other investigators (Bowling et al., 1977; Dolezal et al., 1982; Harrison et al., 1978; Meyer et al., 1960; Schroeder et al., 1980), however, it must be noted that in this study fat from grain-fed animals was added in an attempt to minimize some of the differences in sensory characteristics associated with meat from grass-fed animals.

10. CONSUMER PANEL EVALUATION

The 36-member consumer panel indicated that there were no significant differences in acceptance of the restructured steaks or action that would be taken by the consumer towards the steaks that could be attributed to cooking method, fat level, or the number of

Table 12--Effects of days on feed on the sensory characteristics of restructured steaks[a,b,c]

Characteristic[d]	Days on feed 0	28	56	84
Appearance	80.7x ± 34.2	87.0y ± 34.9	89.7y ± 31.4	77.9x ± 38.5
Softness	49.2x ± 31.4	47.2x ± 31.4	45.0x ± 27.9	48.1x ± 27.0
Chewiness	72.4x ± 30.4	70.3x ± 31.4	71.9x ± 28.8	71.7x ± 24.8
Moisture release	65.5x ± 40.2	61.4x ± 36.4	67.8x ± 39.1	58.5x ± 34.9
Greasiness	57.9x ± 30.0	52.3x ± 31.3	56.9x ± 31.5	61.4x ± 30.6
Off-flavor	40.4x ± 35.7	43.7x ± 35.2	44.4x ± 35.6	47.2x ± 35.0
Acceptability	84.7x ± 33.1	84.6x ± 30.6	85.0x ± 29.3	81.0x ± 33.2

[a]Means ± SD representing both cooking methods, all fat levels, and three replications.

[b]Means within a row followed by different letters differ at $P<0.05$. Means ± standard deviation.

[c]Number of judges = 10.

[d]1 = rare, very soft, yields readily, slight, not at all difficult, no off-flavor, not acceptable; 150 = well-done, very hard, highly resistant, great, very difficult, extreme off-flavor, extremely acceptable.

days an animal was on grain (Tables 13, 14, 15). All of the steaks were scored as "slightly like" or "neither like or dislike." Potential action towards the steaks was scored to be limited. It is hypothesized that if the samples had been served immediately after removal from the oven, scores would have been higher. Consumers are familiar with meat that is served warm and the room-temperature meat may have imparted a negative effect.

Similar results for acceptance score for beef patties with 15% and 30% fat were reported by Drake et al. (1975). No difference in acceptability of flavor or texture was found by the 32-member panel.

11. CORRELATION OF OBJECTIVE AND SENSORY MEASUREMENTS OF TENDERNESS

There has not been much reported on the objective evaluation of tenderness of restructured steaks. Different objective measurements of tenderness should be evaluated and correlated with sensory evaluation scores of tenderness. Correlations for objective and sensory values are shown in Table 16. A significant correlation existed between penetration hardness and chewiness values and sensory evaluation scores for softness and chewiness. There were no significant relationships between Warner-Bratzler shear values and softness or chewiness scores. In the past, correlation coefficients for Warner-Bratzler shear values and sensory scores for tenderness have varied over a wide range; however, samples usually were from

Table 13--Hedonic and FACT scores for restructured steaks cooked in microwave and conventional ovens[a,b]

Scale	Microwave	Conventional
Hedonic[c]	3.5 $\pm$ 1.6	3.5 $\pm$ 1.6
FACT[d]	2.0 $\pm$ 1.5	2.1 $\pm$ 1.4

[a]Means $\pm$ SD representing all fat levels and all days on feed; no significant differences between means.

[b]Number of judges = 36.

[c]1 = extremely dislike; 7 = extremely like.

[d]1 = I would hardly ever buy this; 6 = I would buy this very often.

Table 14--Hedonic and FACT scores for restructured steaks with varying fat levels[a,b]

Scale	Fat level, %		
	15	20	25
Hedonic[c]	3.4 ± 1.7	3.4 ± 1.7	3.7 ± 1.5
FACT[d]	2.0 ± 1.5	2.0 ± 1.5	2.3 ± 1.4

[a]Means ± SD representing both cooking methods and all days on feed; no significant differences among means.

[b]Number of judges = 36.

[c]1 = extremely dislike; 7 = extremely like.

[d]1 = I would hardly ever buy this; 6 = I would buy this very often.

Table 15--Hedonic and FACT scores for restructured steaks produced from animals fed grain for 0, 28, 56, or 84 days[a,b]

	Days on feed			
Scale	0	28	56	84
Hedonic[c]	3.6 ± 1.6	3.5 ± 1.6	3.4 ± 1.7	3.5 ± 1.7
FACT[d]	2.1 ± 1.5	2.1 ± 1.4	2.0 ± 1.5	2.1 ± 1.5

[a]Means ± SD representing both cooking methods and all fat levels; no significant differences among means.

[b]Number of judges = 36.

[c]1 = extremely dislike; 7 = extremely like.

[d]1 = I would hardly ever buy this; 6 = I would buy this often.

Table 16--Pearson Product Moment correlation coefficients (r) for sensory attributes and objective measurements of restructured steaks

Objective measurement	Sensory attribute			
	Softness	Chewiness	Moisture Release	Greasiness
Warner-Bratzler shear values	0.10	-0.04	-0.02	-0.07
Penetration Hardness	0.59**	0.41**	0.72**	0.30*
Penetration Cohesiveness	0.19	-0.15	0.14	0.22
Penetration Chewiness	0.45**	0.31*	-0.56**	-0.14
Cooking losses	0.40**	0.44**	-0.42**	0.08
Expressible moisture	0.01	0.26*	0.11	0.29*

*P<0.05.

**P<0.01.

intact muscles. It appears that for restructured steaks, penetration with a flat probe may be a good indication of tenderness as evaluated by a sensory panel.

Other significant correlations were found between penetration values and sensory scores for moisture release and greasiness. It appeared that as force required to penetrate the samples increased, moisture and greasiness scores decreased. These results concur with objective indicators of tenderness reported earlier. Samples with greater levels of fat needed significantly less force to shear than did samples with lower fat levels. Also, microwave-heated steaks with greater cooking losses were found to need more force to penetrate than did broiled steaks.

A significant negative correlation existed between total cooking losses and sensory scores for moisture release. As cooking losses increased, the panelists reported a decrease in moisture released.

Greasiness was found to be positively correlated with expressible moisture values. Expressible moisture values usually are considered to indicate free water present (Pedersen, 1978); fat present in the meat should be considered.

CHAPTER V

SUMMARY, LIMITATIONS, AND IMPLICATIONS

The present study was undertaken to examine the objective and sensory characteristics of restructured steaks. The variables that were investigated were cooking method, level of fat in the steaks, and number of days an animal was on grain. The raw materials used in this study were top rounds from animals fed grain for 0, 28, 56, or 84 days and beef plates (approximately 55% fat) from animals fed grain for at least 150 days. The restructured steaks were formulated to contain 15%, 20%, or 25% fat and were heated in a microwave oven on a browning dish or broiled in a conventional oven.

It was of interest to note the composition of restructured steaks because limited information has been reported. Regardless of cooking method, fat level, or days on feed, cooked steaks had a moisture range of 48% to 50% and fat range of 18% to 23%. Knowledge of these values may help the consumer in acceptance of these products.

A comparison of cooking methods indicated conventional heating required approximately 132% more time for cooking the steaks than did the microwave oven. The energy required by the conventional oven was 393% greater than that required by the microwave oven. It was shown that cooking in a microwave oven was much more advantageous than was cooking in a conventional oven if savings in time and energy were the major concern.

Microwave cooking appeared to be somewhat detrimental to some of the objective and sensory characteristics evaluated. Cooking losses and penetration hardness, cohesiveness, and chewiness were greater for steaks cooked in the microwave oven than were for conventionally-heated steaks. Sensory panelists' scores also indicated that microwave-heated steaks were harder and released less moisture than did steaks heated in the conventional oven. Differences may be attributed to greater heat penetration for steaks cooked in the microwave oven than found with conventional heating.

Fat level also affected many of the time and energy measurements of the restructured steaks. As the level of fat increased, cooking time and energy consumed decreased. Fat has a lower specific heat than does water; therefore, heat will penetrate at a faster rate and foods will cook quicker.

Sensory scores indicated that the levels of fat positively affected the sensory characteristics of the steaks. As the level of fat increased, softness, juiciness, and acceptability also increased. Higher level of fat in the steaks also contributed to less off-flavor than was found with lower fat levels.

The number of days an animal was on grain did not influence any of the sensory scores except appearance. The number of days an animal was on feed was previously shown to influence tenderness, juiciness, and off-flavor. In the present study, the addition of fat (beef plates) from grain-fed animals to restructured products was investigated in an attempt to minimize problems associated with meat from grass-fed animals.

A 36-member consumer panel found no differences in acceptability or potential action that they would take toward the steaks that could be attributed to cooking method, fat level, or the number of days an animal was on grain. Steaks were rated as slightly like to neither like nor dislike. It was postulated that if the steaks were served upon removal from the oven and in a form familiar to the panelists, acceptability scores would have been higher.

Another limitation of this study was that the sensory panel was conducted over a four-month period. The study was set up this way to minimize the effect of freezer storage on the steaks. To alleviate both problems, the study should be set up so that steaks from animals of all feed regimes could be formulated on the same day. Evaluation of the steaks by a sensory panel could also occur in the same day.

The implications of this study are many. Grass-fed beef may be restructured to yield products that are as acceptable as products from animals on grain for 84 days. Whether improvement was attributed to restructuring or addition of beef plates from grain-fed animals is not known; however, the high cost of beef may force industry and consumers to find a substitute and restructured steaks from meat from grass-fed animals may be the answer.

Fat level positively influenced objective and sensory characteristics of the restructured steaks. Steaks that contained 20% and 25% fat were similar in many of the objective and sensory

characteristics. It would be advantageous for industry to use a less expensive product, fat, that could be incorporated into restructured meat to form an acceptable form. However, consumers are concerned about fat level and type of fat present in meat products. It should be noted that fat levels for the cooked products in this study only differed by 5%.

Microwave heating of meat saves time and energy. Convenience is another feature that makes microwave-heating desirable. Unfortunately, microwave-cooked steaks exhibited some negative qualities that would probably deter consumers from cooking in the microwave oven. Further research with variable power levels needs to be undertaken to further examine the effects on restructured steaks.

Any objective evaluation of new products raises the question if significant differences are of practical importance. Correlation coefficients reflected that some objective indications of tenderness are related to sensory evaluation of tenderness. Cooking losses and expressible moisture index also were found to be correlated with moisture release and greasiness, respectively. Further investigation of appropriate methods to evaluate restructured steaks needs to be examined.

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APPENDICES

APPENDIX A

DETERMINATION OF WATTAGE AND COOKING POWER OF THE CONVENTIONAL OVEN

I. Rotating Disc Method for Determination of Wattage of Conventional Oven (Luetzelschwab, 1980; Korschgen et al., 1980):

1. Attach watt-meter to oven.

2. Turn on oven. Time the revolution of the disc on the watt-meter. Use the black indicator mark on the disc for a signal to start and stop timing.

3. Determine oven wattage by multiplying Kh value (taken from meter) by 3,600 (number of seconds in an hour) and divide by the rotating time of the disc.

4. Time for one disc revolution = ____ seconds; wattage = 3,600 x ____ Kh value ÷ seconds for one disc revolution = ____ watts of bake element.

II. Determination of Cooking Power and Relative Efficiency of Conventional Oven:

1. Operate oven without a load and record watt hours and time.

2. Determine rate of energy consumption.

$$\frac{\text{watt hours}}{\text{minutes}} = \frac{\text{total watt hours consumed}}{\text{time of test}}$$

3. Calculate cooking power (energy for cooking).

$$\text{cooking power} = \begin{matrix}\text{watt hours to}\\ \text{cook steaks}\end{matrix} - \left(\begin{matrix}\text{rate of energy}\\ \text{consumption}\end{matrix} \times \begin{matrix}\text{time to}\\ \text{cook steaks}\end{matrix}\right)$$

4. Calculate relative efficiency without preheating.

$$\%\ \text{RE} = \frac{\text{cooking power}}{\text{watt hours to cook steaks}} \times 100$$

5. Calculate relative efficiency with preheating.

$$\%\ \text{RE} = \frac{\text{cooking power}}{\text{watt hours to preheat + watt hours to cook steaks}} \times 100$$

APPENDIX B

DETERMINATION OF COOKING POWER AND RELATIVE EFFICIENCY

OF THE MICROWAVE OVEN

I. Determination of efficiency and cooking power of microwave oven for cooking water loads (Gerling, 1978; Van Zante, 1973).

To determine the efficiency with a water load:

1. Plug in watt-meter and oven.

2. Weigh out 100, 275, 500, 2,000 g of water into appropriately sized beakers.

3. Weigh out 1% by weight of salt for each beaker.

4. Record initial temperature.

5. Stir with a wooden spoon before and after heating.

6. Heat in oven in order to cause a 25-degree temperature rise.

7. Measure temperature immediately after stirring.

8. Repeat 2 times for each load.

9. Repeat for different positions in the oven, at different times of day, and at the high power level.

10. Calculate sensible heat (H).

    $H = m \times c \times t$

    m = mass, g

    c = specific heat in calories/gram/°C

    t = rise in liquid in °C

11. Multiply H x 1.16222×10^{-6} to convert from small calories to kilowatt hours.

12. $$\text{Output} = \frac{\text{calculated or measured kilowatt hours}}{\text{time to cook}} \times 3600 \text{ sec} \times \frac{10^3 \text{ watt hours}}{\text{kilowatt hours}} = \text{watt hours}$$

II. Determination of cooking power and relative efficiency of microwave oven for cooking steaks:

1. $$\text{Sensible heat of water in watt hours} = m \times c \times \Delta t \times 1.16222 \times 10^{-3}$$

2. Determine rate of energy consumption.

$$\frac{\text{watt hours}}{\text{minutes}} = \frac{\text{total watt hours for water load} - \text{sensible heat (wh)}}{\text{time to cook water (min)}}$$

3. Calculate cooking power to cook steaks.

$$\text{cooking power} = \text{watt hours to cook steaks} - \left(\text{rate of energy consumption} \times \text{time to cook steaks}\right)$$

4. Calculate relative efficiency.

$$\%\ RE = \frac{\text{cooking power}}{\text{watt hours to cook steaks}} \times 100$$

APPENDIX C

MEDIA, INCUBATION TIME, AND INCUBATION TEMPERATURE FOR MICROORGANISMS

Organisms	Media	Incubation
Aerobic (psychrophiles)	Standard Methods Agar (SMA)	72 hr. at 21°C
Aerobic (mesophiles)	Standard Methods Agar (SMA)	48 hr. at 35°C
Coliform	Violet, Red, Bile Agar (VRB)	24 hr. at 35°C
Yeast, mold	Potato Dextrose Agar (PDA)	120 hr. at 21°C
Staphlococcus	Baird Parker (BP)	48 hr. at 35°C
Salmonella	Brillant Green Agar (BGA)	24 hr. at 35°C
Lactobacillus	Lactobacillus Selective Media	72 hr. at 35°C

APPENDIX D

SCORECARD FOR SENSORY PANEL

Name ______________________ Sample Number __________________

Appearance

____

Well done Rare

Softness to tooth pressure

____

Very soft Very hard

Moisture release

____

Great Slight

Chewiness

____

Highly resistant Yields readily

Greasiness

____

Not at all difficult Very difficult

Off-flavor

____

No off-flavor Extreme off-flavor

Overall acceptability

____

Extremely acceptable Not acceptable

APPENDIX E

SENSORY CHARACTERISTICS, SCALE ANCHORS AND PROCEDURES FOR EVALUATION

Characteristics	Scale anchors	Procedure
Appearance	Rare-well done	Before tasting, visually judge apparent doneness.
Softness to tooth pressure	Very soft-very hard	Rate amount of force needed to bite through sample.
Moisture release	Slight-great	After 2 or 3 chews, judge the amount of moisture released.
Chewiness	Yields readily-highly resistant	Judge the amount of work required to prepare sample for swallowing.
Greasiness	Not at all difficult-very difficult	Judge the difficulty of removal of fatty film that coats the mouth
Off-flavor	No off-flavor-extreme off-flavor	Evaluate the presence of undersirable flavor
Overall acceptability	Not acceptable-very acceptable	Give your individual judgment of acceptability.

90

APPENDIX F

EXTREMES FOR CHARACTERISTICS EVALUATED BY SENSORY PANELISTS

Characteristic evaluated	Lower extreme	Higher extreme
Softness to tooth pressure	Frankfurter without skin	Top round broiled to well-done
Chewiness	Frankfurter without skin	Top round broiled to well done
Greasiness	Ground beef (≈ 15% fat)	Ground beef (≈ 33% fat)
Off-flavor	Ground beef	Ground beef from animals fed grass

APPENDIX G

SCORECARD FOR CONSUMER PANEL

Panel Number ___________

Check the appropriate response to indicate how well you like or dislike each of the samples. Rinse your mouth between samples with the water provided.

	SAMPLE NUMBER
	________
Extremely like	________
Moderately like	________
Slightly like	________
Neither like or dislike	________
Slightly dislike	________
Moderately dislike	________
Extremely dislike	________

Check the appropriate response to indicate your attitude towards each sample.

	SAMPLE NUMBER
	________
I would buy this very often	________
I would frequently buy this	________
I would buy this now and then	________
I would buy this if available but would not go out of my way	________
I don't like it but would buy it on occasion	________
I would hardly ever buy this	________

APPENDIX H

TABLES

Table A-1--Mean squares and significance of F ratios for energy measurements of restructured steaks with varying fat levels cooked in conventional and microwave ovens

Source of variation	df	Mean squares: Cooking time without preheating	Cooking time with preheating	Watt hrs. without preheating	Watt hrs. with preheating	Cooking power	Relative efficiency
Total	285						
Oven	1	4197.32**	3169.85**	16616434.85**	23563623.77**	25893.59**	74921.20**
Fat	2	45.46**	45.46**	49570.81**	47885.83**	882.87	15.22
Fat x Oven	2	4.58*	4.58*	33236.94**	34921.92**	236.12	80.20*
Residual[a]	280	1.49	1.49	3114.17	3114.17	414.11	21.34

[a]Error term for all sources of variation

*P<0.05.

**P<0.001.

Table A-2--Mean squares and significance of F ratios for objective measurements of restructured steaks with varying fat levels cooked in conventional and microwave ovens

Source of variation	df	Expressible moisture	Cooking losses	Warner-Bratzler shear	Penetration hardness	Penetration cohesiveness	Penetration chewiness
Days on feed	3	0.1364	437.88*	61368.15*	6989.96	0.0071	1020.06*
Oven	1	0.0221	1956.72**	90607.65*	57208.55**	0.0658*	13472.64**
Fat	2	0.0330	59.74*	36461.94*	105100.27**	0.0547*	7052.02**
Fat x Oven	2	0.0051	39.47*	29878.59	3526.64*	0.0165	494.67
Replication (Days on feed)[a]	8	0.0532	17.78	7850.77	5716.85	0.0363*	16170.78**
Days on feed x Fat x Oven x Replication[b]	40	0.0113	7.78	10846.71	917.54	0.0136	351.00
Residual	216-503[c]	0.0030	4.93	10435.29	859.78	0.0115	359.23

[a]Error term for days on feed.

[b]Error term for oven, fat, and fat x oven.

[c]Range due to number of values for each measurement and missing data.

*$P<0.05$.

**$P<0.001$.

Table A-3--Mean squares and significance of F ratios for sensory evaluation scores of restructured steaks with varying fat levels cooked in conventional and microwave ovens

Source of variation	df	Mean squares						
		Appearance	Softness	Chewiness	Moisture	Greasiness	Off-flavor	Acceptability
Days on feed	3	5273.12	573.48	141.22	3060.12	2402.1	1414.88	620.27
Oven	1	231443.25**	20765.82**	30974.77**	71228.03**	477.77	1147.69	5746.58*
Fat	2	3443.34	11255.53**	6406.43**	59156.74**	7829.44**	16809.27**	17655.08**
Fat x oven	2	3891.92*	1825.40	2596.29*	4370.82*	630.98	1005.58	2051.22**
Replication (Days on feed)[a]	8	2184.98	744.91	1987.5	1233.64	2104.74	839.16	398.35
Days on feed x fat x oven x replication[b]	40	487.41	708.11	608.26	1060.09	919.07	759.01	485.16
Residual	548-552[c]	401.74	577.12	646.34	744.39	646.35	628.02	571.50

[a]Error term for days on feed.

[b]Error term for oven, fat, fat x oven.

[c]Range due to missing data.

*P<0.05.

**P<0.001.

Table A-4--Microbial log counts for restructured steaks produced from animals fed grain 0, 28, 56, or 84 days that contained three fat levels[a]

	Days on feed											
	0			28			56			84		
	Fat level, %			Fat level, %			Fat level, %			Fat level, %		
	15	20	25	15	20	25	15	20	25	15	20	25
Psychrophiles	4.5	3.9	4.5	4.1	4.1	4.1	5.1	4.9	4.8	5.3	5.2	5.2
Mesophiles	3.0	4.0	4.1	3.3	3.8	3.3	4.3	4.5	4.2	5.2	5.0	4.9
Coliforms	3.5	2.2	2.1	2.4	2.5	2.0	3.2	3.4	3.4	3.9	3.5	3.3
Presumptive Staphylococci[b]	3.4	3.2	3.3	3.5	3.8	3.6	4.5	4.2	3.7	4.7	4.6	4.5
Yeasts and molds	<1.0	<1.0	<1.0	2.1	1.3	1.6	1.3	1.8	2.7	<1.0	<1.0	<1.0

[a]No growth was present for Salmonella and Lactobacilli.

[b]Not confirmed by coagulase test.

VITA

Carol A. Costello was born in St. Petersburg, Florida on August 8, 1958. She attended elementary school in Pinellas County and graduated from Dixie Hollins High School in June of 1976. She entered Florida State University in Tallahassee, Florida and completed her Bachelor of Science degree in nutrition in March of 1980. The following June she began graduate studies at The University of Tennessee, Knoxville, with a major in nutrition. During her graduate program she served as an Agriculture Experiment Station research assistant and a teaching assistant in the Department of Nutrition and Food Sciences. In June 1982, she received her Master of Science degree with a major in nutrition.

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