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A COMPARISON OF THE WEIGHT LOSS, TENDERNESS, AND NUTRIENT RETENTION OF SELECTED MEAT PRODUCTS COOKED UNCOVERED AND IN OVEN FILM

by

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The purpose of this study was to investigate the effect of roasting by electric, gas, or electronic heat on the weight loss, thiamine and riboflavin retention, and shear force values of retail cuts of turkey, beef, and pork. The hypotheses tested were that significant differences in the foregoing parameters would occur between meats cooked uncovered and in oven film.

Thirty cuts of each meat were prepared: three by each heating method, either wrapped in cooking film or unwrapped. Five replications of the respective cooking methods were made. Moisture content of all raw and cooked samples was determined after drying at 140 F for 48 hours and thiamine and riboflavin analyses were made on appropriate samples by standard fluorometric procedures. For tenderness determination, shear force values were recorded from cores taken in three positions of a cooked sample of each meat. Shearing of the cores was performed using a Warner-Bratzler shear machine. Statistical analysis of the data was computed through a TSAR Fortran computer program for three-way analysis of variance using F ratios.

It was found that conventional cooking required five times the cooking time of that used for electronic cooking. Wrapping of meats increased cooking losses with conventional ovens; however, losses from meats cooked unwrapped by

electronic heat were significantly higher. The largest percentage of weight loss occurred in unwrapped pork cooked by electronic heat.

Thiamine and riboflavin retention of the cooked meats did not vary significantly when cooked wrapped or unwrapped with any heat. However, thiamine retention of wrapped and unwrapped products was significantly higher in pork than in other meats. No significant variations were reported for riboflavin retention by any method for any meat.

Shear force values were lowest in meats cooked in film by electric heat and values differed according to the position from which the cores were taken.

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CHAPTER I

INTRODUCTION

The term meat, as commonly used, includes the edible portion of mammals, and is the most expensive and perishable item in the diet. In the United States, meat and poultry play similar roles in meal planning and nutrition. Tenderness, juiciness and flavor are considered the most important characteristics in evaluating the eating quality of meat. Generally, more attention is given to tenderness than to other characteristics in meat, since juiciness can be enhanced by liquids and flavor altered by browning and seasonings. In addition to preferences based on palatability, foods from animal products represent concentrated sources of most of the nutrients required by man.

Statement of the Problem

The method of cooking recommended for specific cuts of meat has been based on the classification of cuts as tender or less tender according to the relative quantity of connective tissue and fibers in the muscle. Usually moist heat is recommended for less tender cuts to hydrolyze and soften the collagen in connective tissue; whereas, dry heat is recommended for tender cuts. In general, cooking time is longer, weight and nutritive losses are less and tender cuts are more palatable when meat is cooked by dry heat than by moist heat. Due to the development of ovenproof cooking wraps (polyester or nylon films) in the 1960's, additional information on cooking with moist heat is not only available but necessary.

Cooking films, developed as a convenience to consumers for food preparation, have had limited acceptability. Reports revealed irregularities in performance, such as bursting of the film in the oven, followed by small oven fires with possible burns to the user. The incidence of failures reported was small in relation to the number of films used by consumers, but the conditions warranted investigation.

Super-heating (bumping) is likely to occur when water covered with oil is exposed to high temperatures because the oil inhibits evaporation through boiling which is the principal means for water to release heat. Therefore, to prevent bumping, boiling must be induced. Studies by commercial firms have shown that the best approach for inducing boiling is by nucleation: the introduction of foreign particles to the water. Flour and household seasonings have been found to produce nucleation and the addition of one tablespoon of flour was approved by the Food and Drug Administration for inclusion in instructions for use with the cooking films.

During preliminary investigation, a series of comparisons was made with meat, fish, and fowl prepared in six cooking films employing household type electric, gas, and electronic-conventional combination ranges. Over 250 tests were conducted with ten products: pork roast, turkey breast, duck, chicken, beef pot roast, beef short ribs, lamb, meat loaf, and fish. The factors investigated were: (a) weight loss of the product; (b) natural juices (drippings) lost during cooking; (c) color of finished product; (d) conditions of film after product preparation; and (e) adherence of the product to the film after cooking.

It was found in this preliminary investigation that tenderness and palatability increased whereas cooking times were decreased markedly by use of cooking films. The Brown-n-Bag$_{TM}$[1] performed acceptably with products cooked in an electronic oven in this study. Less juice was lost from products cooked in this cooking film than all other films tested. Further work suggested by the study was related to method of increasing the palatability of products cooked in the electronic oven.

The many possible applications of electronic heating have created interest in determining the beneficial or destructive effects this process might have on nutrient retention. Greater retention of several nutrients has been

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[1]Reynolds Metals Co., Richmond, Virginia.

observed with electronic blanching of vegetables. The retention of thiamine and riboflavin in beef roasts when prepared in an electric oven was greater than similar roasts cooked in the electronic range. Other studies to determine nutrient retention of meats in cooking film prepared in conventional and microwave ovens have not been reported.

Therefore, the present investigation was conducted to study the combined effects of variation in kind of heat and cooking method on such factors as weight loss, shear force, and thiamine and riboflavin retention in selected meat products.

Hypotheses Tested

Using electric, gas, and electronic ranges to prepare selected meat products, it was hypothesized that:

- there would be significant differences in the weight loss of products cooked uncovered and in the oven film.
- there would be significant differences in the thiamine and riboflavin retention of products cooked uncovered and in the oven film.
- there would be significant differences in the shear force values of products cooked uncovered and in the oven film.

Definition of Terms

Brown-n-Bag$_{TM}$. Trade name given to cooking film made from nylon by the Reynolds Metals Company of Richmond, Virginia. The film used in this study, size 17" x 22" sealed along three sides, is recommended for cooking turkey.

Tight-wrap method. A method in which both the sealed and open ends of the film are securely fastened close to the products.

Assumptions

It was assumed that the results of this study would be most applicable to products prepared by consumers. Therefore, conventional-type ovens were used throughout cooking procedures. The author also assumed that reviewed studies used conventional methods for roasting meat products so a separate section concerning electric and gas ovens was not included in the Review of Literature.

CHAPTER II

REVIEW OF RELATED LITERATURE

Cooking can make meat more or less tender than the original raw cut, depending on the amount and kind of heat applied. According to Potter (1968), when meat is cooked, three tenderizing influences occur: fat melts and contributes to tenderness; connective collagen dissolves in the hot liquids and becomes soft gelatin; and muscle fibers separate to make the tissue more tender. Overheating, on the other hand, causes the muscle fibers to contract making the meat shrink and become tougher and increases moisture evaporation producing drier, less tender tissue (Potter, 1968).

Meat Cookery

Some of the theories on meat cookery developed and applied early in this century have been reexamined and revised. One of these theories is that moist heat is required to cook less tender cuts because added moisture is required to break down the large amount of collagen present. Another theory, that high temperatures should be avoided to prevent toughening meat, requires qualification. An example is that steaks may be very tender when broiled at 550 F, whereas an oven temperature of 400 F is considered too hot for roasting meat. This theory then could be restated to say that high temperatures applied for long periods toughen meat (Griswold, 1962).

According to accepted usage, roasting means cooking uncovered by dry heat. This term is distinguished from pot-roasting which is a moist heat method. Dry heat results in meat quite different from that produced by roasting in a covered pan or in a wrapping since covering retains moisture given off by the meat and/or added liquid, resulting in moist heat cookery.

When the meat is roasted, cooking losses consist of the drippings that remain in the pan and the water that evaporates from the meat. The evaporation loss is found by subtracting the weight of the cooked roast and drippings from the original weight of the roast. These losses which occur continuously during cooking increase as the end point temperature of the meat or the oven temperature is increased (Dawson, Linton, Harkin and Miller, 1959; Bramblett, Judge, and Harrington, 1970; Davis, Funk and Zabik, 1973).

Several researchers (Cover, 1943; Bramblett, et al., 1959; Marshall, Wood and Patton, 1959) have observed that meat is likely to be tender if roasting time is long, but the general conclusion from such studies was that the effect is due to the long time rather than to the low temperature used. In another experiment (Cover, 1941), the rate of heat penetration was increased by cooking in water instead of in air. Water conducts heat much more rapidly than air; therefore, the meat studied required three hours to cook in simmering water but more than 23 hours in a conventional oven at the same temperature (194 F).

Cooking in steam has an effect similar to that of cooking in water because steam conducts heat more rapidly than air. Using a specially built oven in which the humidity was high and the air flow low Griswold (1962) noted that roasts cooked faster and were less tender than those cooked in a regular gas oven when both temperatures were held at 275 F. Hood (1960) reported that foil-wrapped roasts lost more weight during cooking and were judged less juicy, less tender, and less satisfactory in flavor than roasts cooked by dry heat. Ferger, Harrison and Anderson (1972) stated that percentages of total loss and drip loss, based on weight of frozen lamb roasts, were not significantly different in dry and moist heat and that the volume of drippings from lamb roasts cooked by moist heat was greater than that from roasts cooked by dry heat. Total cooking losses from beef roasts were not affected significantly by type of heat or oven temperature. Ruyack and Paul (1972), reported that cooking times were significantly less and cooking losses greater for roasts cooked by microwave than by conventional heating and the use of polyester wrap increased the cooking losses for both heating methods.

Beef

Beef muscles decrease in weight during cooking and usually shrink in length and width, while expanding in height. The extent of the shrinkage and expansion varies with different muscles and the degree of doneness to which the meat is cooked (Winegarden, Lowe, Kastelic, Kline, Plagge and Shearer, 1952). In a study to determine effects of cooking temperature and time on the tenderness of beef, Tuomy, Lechnir and Miller (1963) reported that the initial effect of heat was toughening. Data scatter indicated that the innate tenderness of the cooked meat controlled the tenderness at any given temperature and time. Since the shorter cooking cycles produced beef that, on the average, was tough, these same authors concluded that cooking cycles needed to be extended to obtain an acceptable tenderness level.

Pork

Standard procedures for roasting pork loins, as announced by the National Live Stock and Meat Board (1966) now specify an end-point temperature of 170 F instead of the previously recommended 185 F (a temperature thought necessary to destroy the pathogenic micro-organism, *Trichinella spiralis*). This change has been influenced by the development of meatier animals through improved breeding and feeding practices.

An internal temperature of 136.7 F allows a 19 F safety margin for the destruction of Trichinella spiralis. Since many meat thermometers are not extremely precise and some error may result from a failure to center the thermometer, Bramblett, et al. (1970) recommended an internal temperature of 149 F as a minimum for Trichinella spiralis destruction. Pengilly and Harrison (1966) suggested from their study with pork loins that an end-point of 167 F would be satisfactory. With the reduction in fatty tissues of pork cuts, high end-point temperatures to develop desirable textural qualities are no longer necessary (Bramblett, et al., 1970). These same authors, when comparing boned and rolled fresh hams and shoulders, concluded that an end-point of 170 F is satisfactory for these products. Webb, N. L., Webb, N. B., Cederquist and Bratzler (1960) reported from their investigation with pork loins that tenderness and juiciness improved as degree of doneness was reduced to the safety point.

Poultry

As in the case of red meats, tenderness of poultry flesh is favored by young birds, by low amounts of connective tissue, and by relatively high amounts of fat within the tissue (Potter, 1968). Several methods of roasting frozen chickens have been compared and reported by Griswold (1962). Roasting uncovered at 300 F proved satisfactory. Although the thigh muscles were equally desirable whether covered or uncovered, the breast was more palatable when the chicken was roasted uncovered. Covering for a part of the cooking period increased the tenderness and palatability of the skin but not of the meat. Esselen, Levine and Brushway (1956) reported that roasting the turkey in its original plastic film wrapper shortened the cooking time but produced unattractive splitting of the meat. They also reported similar results when the fowl were roasted in aluminum foil. Satisfactory determinations of end point temperatures are difficult with poultry because the muscles are small and have a tendency to separate during cooking. However, the large size of turkey breast and thigh muscles make them fairly satisfactory for this purpose (Griswold, 1962).

Lower cooking temperatures for a longer period of time, in general, produce more tender results than higher temperatures for shorter periods of time. Use of new methods of heating and/or use of cooking films may change such concepts.

Electronic Cooking

Radio frequency heating, also known as electronic, dielectric, or high frequency is a fast rate of heating obtained from microwave energy. The application of microwave energy to blanching, cooking, pasteurizing, thawing and drying has been studied and its advantages and disadvantages discussed (Thomas, et al., 1949).

Microwaves are part of the electromagnetic spectrum with frequencies ranging from 300 MH_z to 300,00 MH_z. Microwaves are generated by radio frequency power tubes called magnetrons, klystrons, and amplitrons. In most countries government departments or agencies have set aside four microwave frequencies for industrial, medical, and scientific use. Due to the availability of power tubes the most commonly used frequencies are 915 and 2450 MH_z (Tape, 1970).

Contrary to conventional heating which depends on the conductive capacity of the material being heated, any substance containing free polar molecules is affected by microwave energy. Since water molecules are polar and are distributed fairly uniformly in foods, heating foods with microwave energy is possible. When a food is subjected to microwave energy the randomly oriented water molecules align themselves with the electromagnetic field. The polar molecules then rotate around their axes millions of times per second, thereby creating friction which results in heat (Tape, 1970).

Studies on meat were included in early research dealing with the effect of electronic cooking on various foods. Some undesirable results were reported, including lack of or unnatural surface browning, development of hard crusts, uneven cooking and increased cooking losses (Bollman, Brenner, Gordon, and Lambert, 1948).

Apgar, Cox, Downey and Fenton (1959) reported that total weight losses from pork patties and roasts did not differ significantly when the meat was cooked by conventional and electronic methods. Although all meat samples were considered acceptable, scores for individual palatability factors varied with the cooking method and the cut of meat. Marshall, et al. (1960) also reported that average scores for appearance, tenderness, juiciness, and flavor were lower for meats prepared electronically.

Headley and Jacobsen (1960) reported that although rolled paired leg of lamb roasts attained approximately the same maximum temperature, 180 F, those prepared by the conventional method were scored higher for juiciness and flavor. They also reported that those lamb roasts cooked electronically appeared to be more well done and had higher average color scores. In addition, greater cooking losses and shrinkage occurred during microwave cooking than during conventional.

Ruyack and Paul (1972) concluded that the increase in drip losses observed with polyester wrap was due to the effect of microwaves on polar water molecules within the meat. They believed that the constant change in the magnetic field caused the water molecules to oscillate and that such oscillation might affect the bonding of the bound water and result in greater moisture loss.

In reviewing the status of microwave cooking in 1947, Brown, Hoyler and Bierwirth commented on the low efficiency of this source of energy. Fenton (1950) imputed a high efficiency to microwave cooking based primarily on the assumption that the extremely short cooking time with microwave equipment must use less electrical energy than the longer cooking times of conventional equipment. Pollak and Fein (1960) studied the heating efficiency of microwave and conventional cooking equipment in the roasting of beef and found that in roasting 8-pound ribs of beef, the overall electrical efficiencies were 36.7 per cent for the conventional oven and 33.4 per cent for the microwave oven. However, the product prepared in the electric oven yielded 13 per cent more edible meat using 24 per cent less electrical energy. The energy required to prepare a unit weight of edible product was found to be 74 BTU per ounce of yield for the conventional oven as compared to 119 BTU per ounce of yield for the microwave oven. The difference in energy used was attributed primarily to the energy required to evaporate a greater amount of water in microwave cooking.

Headley and Jacobson (1960) concluded that electronic cooking of lamb roasts was four times as fast as conventional roasting. They found that an average cooking time of 13 minutes per pound was required for the electronic method as compared with 52 minutes per pound for the conventional method. More data is needed before total efficiency of this type of heat for home cooking can be determined.

Thiamine and Riboflavin Retention

According to Cheldelein, Woods and Williams (1943), meats are found to contribute one-fifth of the total riboflavin supply to the diet and one quarter of the thiamine supply. In the meat category, pork is the principal thiamine contributor. Michelson, Waisman, and Elvehjem (1939) found the liver and kidney of pork, beef, lamb and veal to be uniformly higher in riboflavin content than other organs of these species. They reported no loss of riboflavin by stewing as contrasted with losses of from 33 to 60 per cent by pan broiling and roasting. McIntire, et al. (1943) reported the average thiamine retention in pork to be 70 per cent after roasting and broiling and 50 per cent after braising. The riboflavin retention averaged 85 per cent with all cooking methods. A wide variation in the thiamine and riboflavin contents of different pork carcasses was also reported.

Schweigert, McIntire and Elvehjem (1944), in a study comparing the roasting, braising and broiling of fresh and cured hams, reported the average retention for meat alone to be 58 per cent for thiamine and 74 per cent for riboflavin. Considerable variation was noted in the thiamine content of different sections of the ham while the riboflavin values were more constant. Brady, Peterson and Shaw (1944) reported that marked differences may occur not only between various muscles within the same cut but also within different sections of the same muscle.

Tucker, Hinman and Halliday (1946), working with fried, broiled, and braised beef, attributed the higher nutrient retentions in fried steaks to the shorter cooking times. Cover, McLaren and Pearson (1944) obtained higher thiamine retention in rare than in well-done roasts. The cooking time was shorter for the rare roasts than for the well-done roasts, and the internal meat temperature was lower in rare roasts. Cover, Dilsaver, Hays, and Smith (1949) and Mayfield and Hedrick (1949) reported that roasts cooked for a longer time at low oven temperatures retained more thiamine than those cooked at high oven temperatures for a shorter time. Moreoever, Cover, Dilsaver, and Hays (1947) used cubes of brisket stewed by 12 different methods, including variations in browning, temperature of cooking, and amount of water. They found that browning appeared to be one cooking variable which significantly lowered thiamine retention. Cover and Smith (1956) suggested that evaporation from the surface of the meat during cooking by dry heat methods or washing of the surface by condensing steam during cooking by moist heat might be important factors affecting retention of thiamine and niacin, and that internal temperature of the meat might also be an important factor in thiamine retention.

Noble and Gomez (1960) summarized research using paired standing rib roasts by stating that longer heating did not affect the thiamine retention in the cooked meat. Lushbough, Heller, Weir and Schweigert (1962), on the other hand, concluded that destruction of thiamine in meat continues throughout the heat processing period.

Meyer, Briskey, Hoekstra and Weckel (1963) reported that the riboflavin values of fresh samples of pork muscles were similar to those reported by others. They also stated that riboflavin content varied less on a fresh-weight basis than the other vitamins, and that more was found in dark than light muscles.

Kylen, et al. (1964), working with boneless rolled beef rib and pork loin roasts, found greater thiamine retention in the drippings after microwave cooking because there were significantly more drippings after microwave than after conventional cooking. However, these investigators believed that since there was longer heating and more browning of the drippings in the conventional oven, there was more destruction of thiamine.

More recently (1972) Bowers and Fryer reported comparisons of turkey in electronic and conventional ovens in regard to thiamine and riboflavin retention. Their findings support those of Lushbough, et al. (1962) who concluded that type of oven had no significant effect on thiamine content. Muscle heated by gas had more riboflavin than did muscle heated by microwave on a moisture-free, fat-free basis. Variation was greater among the turkeys than between the heat sources or among treatments. Data for the niacin, riboflavin and thiamine retentions in beef and pork patties and beef roasts were given by Thomas, Brenner, Eaton and Craig (1949). Thiamine retention was higher when meat patties were cooked in an electronic range than grilled by a conventional method, while similar percentages of niacin and riboflavin were present after both cooking methods. Beef roasts cooked to a medium degree of doneness retained slightly more of all three nutrients after conventional than after microwave cooking.

Griswold, Jans and Halliday (1949) indicated that a soaking process necessary to prepare palatable kidneys resulted in losses of 7 to 19 per cent of thiamine and riboflavin, as well as niacin. Thiamine losses were highest in meat cooked at an elevated temperature, as pressure-cooked hearts, or for a long period, as kidney stew. Retention of riboflavin was good during the cooking of both meats. In more recent studies using variety meats, Noble (1965; 1970) noted that the kind and cut of meat made a significant difference in the average amount of thiamine and riboflavin retained in the combined braised, roasted or simmered samples.

Farrer (1955), in discussing the thermal losses of thiamine from meats, makes the point that, although most of this data is of value as a guide to the home economist, it is worthless to anyone seeking to arrive at fundamentals. He explains such a dichotomy in terms of lack of information on time and temperature of processing. Thirty-five per cent of the values listed by Farrer record both time and temperature conditions, and of these, several give only the final internal temperature of the meat and the total cooking time.

Shear Force Measurement

As previously stated, tenderness of meat is perhaps the most important quality factor determining its consumer acceptability. For this reason, extensive studies have been carried out to develop methods of measuring tenderness and relating it to the eating quality of meat. Although subjective methods are generally time-consuming and often are not entirely reliable, they are the basis of reference for most present-day tenderness testing methods. Results from mechanical or physical methods which are often related to sensory tenderness values have been widely used in studies of meat tenderness. Bailey, Hedrick, Parrish and Naumann (1962) reported that the first use of mechanical measures of meat tenderness was in 1907.

The device most widely used by present investigators is one developed by Warner in 1928 and by Bratzler in 1932. This apparatus, now known as the Warner-Bratzler shear, has been used by many researchers to measure tenderness of meat.

Another mechanical apparatus used currently in meat studies is that developed by Kramer and co-workers for measuring the tenderness of fruits and vegetables. This machine uses hydraulic pressure to force a series of metal plates through a product held in a metal block. A recent refinement of this shear press, called the L.E.E.-Kramer shear press, has a sensitive dial pressure indicator that registers through a proving ring placed between piston and plunger plates (Bailey, et al., 1962).

Hostetler and Ritchey indicated in 1964 that the Warner-Bratzler shearing device was probably the most widely used instrument in measuring meat tenderness. However, there are several sources of variation in the technique of investigators using this device, such as size of the core and method of obtaining the core to be sheared.

One of two methods of obtaining cores for shear determination is commonly used. Coring with the fibers is done so that the orientation of muscle fibers during shearing will be similar for all cores from a steak and for cores from steaks of different muscles. A second method of obtaining cores is to disregard fiber orientation and simply core perpendicular to the cut surface of the steak. When this method is used, the orientation of muscle fibers may vary in cores from different areas within a steak, as well as in cores from steaks from different muscles (Hostetler and Ritchey, 1964). These same authors cited research to determine shear-force values with the Warner-Bratzler shear by two methods on steaks from longissimus dorsi and biceps femoris muscles cooked to 140 and 178 F. With one exception shear values of paired steaks from the same muscle with cores cut parallel were more closely related than shear values of cores from within the same steak cut differently.

Most mechanical methods for measuring tenderness require a uniform section of muscle, as previously stated, but considerable difficulty has been experienced when meat is bored immediately after cooking. Kastner and Henrickson (1969) suggested that the best treatment is to bore meat after it is chilled to 104 F. Another practice that aids in providing uniform cores is that of heating meat samples to an internal temperature of 168 F. Meat heated to this temperature is well cooked, drier, firmer and thus holds its shape better during boring than muscle cooked to a lower temperature (140 F) (Kastner, et al., 1969).

Sharrah, Kunze and Pangborn (1965), in a study using top round roasts and rib roasts from the 9th, 10th, and 11th rib area from 156 animals, found that an objective evaluation of tenderness may do a superior job of categorizing carcasses and cooked meat with regard to final eating quality. However, as shown by their data and the earlier work of Sharrah, et al. in 1964, information is still insufficient on the relation between shear force (and other mechanical measurements) and sensory evaluation of texture and tenderness in meat.

Summary

Meat cookery is one of the areas in which research has not supported some of the recommendations made on the basis of early and less complete information. Studies of the physical organization and structure of muscle tissue as well as the changes which occur during processing and cooking continue. However, the ultimate goal of predicting and controlling the palatability characteristics of meat has not yet been achieved.

CHAPTER III

PROCEDURES

Preparation of Samples

Consumer-sized cuts of United States Department of Agriculture Choice grade meat were used for this study and all products were obtained from a local market at the same time. Cuts of meat were trimmed, individually wrapped in freezer foil and held in a chest-type home freezer at 10 F until needed. A set of six packages of one meat was thawed overnight in a refrigerator (40 F) before roasting the following day.

Arm pot roasts of beef, pork loin roasts and pre-formed turkey breasts[1] were included in this study; ninety pieces of meat, each weighing from 3-5 pounds. The turkey breasts were formed by molding pieces of meat around a turkey breast bone. A sample of approximately 100 gm., cut across the grain of the raw meat, was frozen for nutrient and moisture analysis. The remaining section was weighed, seasoned with 1/4 teaspoon ground black pepper, and placed in roasting pans. A preliminary study had shown that this

[1]Sold under trade-name House of Raeford, Raeford, North Carolina.

amount of seasoning would prevent bumping with cooking film and salt would not provide nucleation.

Six cuts of meat were cooked daily, three by open roasting and three in the Brown-n-Bag$_{TM}$ secured in a tight-wrap. A wrapped and unwrapped roast were cooked simultaneously in each conventional gas and electric oven but alternately in the electronic range.[1]

Cooking periods averaged 30 minutes per pound for products cooked in conventional ovens and six minutes per pound for those cooked in microwave heating. Specific instructions for each product cooked electronically were obtained from the instruction manual with the range. Roasting in conventional ovens was at 325 F for all products. An internal temperature of 165 F was reached for beef roasts and turkey breasts; 170 F was reached for pork roasts. Preliminary test results had indicated an internal temperature of 165 F for similar weight turkey breasts and beef roasts cooked electronically could be reached in 30 minutes. However, only 24 minutes were required to reach the end-point temperature of 170 F for pork roasts. Each cooking procedure was repeated five times.

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[1]Versatronic Range, model # J 856002WH, G. E. Co. of Louisville, Ky.

Objective Measurement

The average shear force value for a 3-inch sample cut across the grain of the cooked meats represented the mean of three positions. These represent the anatomical locations dorsal, medial, and lateral. Three cores, 1.27 cm. in diameter, were taken from the samples of cooked meats after the meats were held overnight in a refrigerator set at 40 F. All of the core samples were sheared (3 shears/core) using a Warner-Bratzler shear machine.[1]

Analytical Methods

Moisture content of all raw and cooked meat samples was determined from the weight difference of a 2-gm. trimmed portion before and after drying for 48 hours at 140 F. Thiamine and riboflavin were determined by the modified fluorometric methods of Conner and Straub (1941) and Peterson, Brady, and Shaw (1943), respectively. In each case, internal standards formed the basis of calculation. Recovery samples to which known amounts of thiamine and riboflavin had been added were run separately. The average recovery of both nutrients from these samples was 96 per cent. Percentage retention of thiamine and riboflavin in the cooked meats was calculated on the basis of the quantity

[1]Model #73051197 G. R. Electric Mfg. Co. of Manhattan, Kansas.

of vitamin present in the total sample, before and after cooking, on a dry-weight basis to avoid moisture variability.

Since both vitamins are sensitive to light, the entire procedure was carried out in a darkened room. For analysis, 20 gm. samples of pork and 50 gm. samples each of beef and turkey were ground in a 10 speed household type blender with 100 ml. 0.04N sulfuric acid for five minutes. Ground homogenates were heated in a boiling water bath for 30 minutes with shaking by hand every eight to ten minutes. After cooling to room temperature, 10 ml. of buffer solution containing 0.05 gm of the enzyme polidase[1] was added to each 100 ml. of homogenate. A reagent blank with the same volumes of 0.04N sulfuric acid and the buffer solution containing the enzyme was prepared. All solutions were incubated in a water bath, held at 104 F, for 24 hours. Extracts were brought to volume with distilled water and filtered through folded Whatman No. 12 filter paper into dry amber flasks.

Five ml. of filtrate was poured into each of two test tubes, A and B. To tube A, 5 ml. of 0.04 per cent acetic acid was added; to tube B was added 5 ml. of working standard (conc. 0.24 mcg. riboflavin per ml.). One ml. of one per cent hydrogen peroxide was also added to each tube. Corks

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[1]Polidase ®-S is available from Schwartz Research, Inc. of Orangeburg, New York, 10962.

were placed in the tubes, and the contents shaken vigorously for 30 seconds. Finally, the solutions were decanted into cuvette tubes for reading. The fluorometer[1] was set according to manufacturer's directions with a second working standard (conc. 0.20 mcg. riboflavin per ml.). Readings were checked between standards and samples. After tubes A and B had been read in the fluorometer, one ml. of sodium hydrosulfite was added to each tube and they were reread. The value of the second reading was used as part of the formula to determine the riboflavin content of the sample (Appendix A). Riboflavin fluoresces in light of wave length 440 to 500 mμ. For that reason, primary filters # 47B and 2A and secondary filter # 58 were used.

Extraction procedures were the same for thiamine as those for riboflavin. Again, solutions were not exposed to either daylight or artificial illumination. With each set of samples, two standard solutions were run through subsequent steps. For purification, the following procedures were observed: a loose glass wool plug was placed in the bottom of the base exchange tubes; stems were filled with Decalso (an absorbent) to a depth of about three inches and the tubes were tapped to eliminate air pockets. The Decalso was moistened with 10 ml. of three per cent acetic acid. A five ml. aliquot of each solution being tested was pipetted

[1]Model 111, G. K. Turner Assoc., Palo Alto, Calif.

onto a column. After all the sample had run through, the columns were washed with three 10 ml. portions of hot water and the washings were discarded. The column was eluted with at least two 10 ml. portions of hot acid potassium chloride solution and the effluent was collected in a 50 ml. volumetric flask. This effluent was then brought to volume with 25 per cent potassium chloride in 0.1 N hydrochloric acid.

Three ml. of ferricyanide reagent was pipetted into one 40 CC. capacity centrifuge tube (A) and 3 ml. of 33 per cent sodium hydroxide was pipetted into another (B). Five ml. of the eluate was added to the first tube (A), followed immediately by 15 ml. of purified isobutanol; the mixture was shaken vigorously for 60 seconds. The same procedure was repeated for the second tube (B). Samples were centrifuged in an 8-place head refrigerated centrifuge[1] for three minutes at 1500 R.P.M. after which the aqueous lower layer was drawn off with a siphon. One-quarter teaspoon of anhydrous sodium sulfate was added and the tube contents were again centrifuged. Samples were read on the fluorometer[2] for determination of the thiamine per given sample. After thiamine is oxidized to thiochrome, fluorescence is measured at 445 mμ by the use of primary filter #7-60 and secondary filters #2A and 47A.

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[1]Model PR-2, International Equipment Co., Boston, Mass.

[2]Model 111, G. K. Turner Assoc., Palo Alto, Calif.

As previously stated, percentage retention of thiamine and riboflavin in the cooked meats was calculated on the quantity of vitamin present in the total sample, on a dry-weight basis. These values were combined in a three-way analysis of variance; a TSAR Fortran computer program was used.

CHAPTER IV

DATA AND ANALYSIS

Introduction

The researcher hypothesized that there would be statistically significant differences of weight loss, thiamine and riboflavin retention, and shear-force measurements in meats cooked in wrap and uncovered. The significance of the difference between these parameters was determined by F-ratios as there was more than one level to each treatment.

Weight Loss

Highly significant weight losses ($p \leq 0.01$) were observed from the types of meat, sources of heat, and from the interactions of these parameters. Meats prepared in the cooking film showed higher percentage weight losses than those cooked unwrapped when cooked in the two conventional ovens, as shown in Table 1. However, losses from meats cooked by electronic heat, unwrapped, were shown to be the highest (Figure 1). Similar results were reported by Ferger, et al. (1972) as well as for various meats cooked electrically, without a covering (Headley and Jacobson, 1960; Ruyack and Paul, 1972).

Further evidence that cooking losses were greater after microwave than after conventional cooking can be found

TABLE 1

MEAN PER CENT WEIGHT LOSS OF MEATS COOKED
WITH VARYING HEAT SOURCE AND COVERING

Covering	Heat Source					
	Electric		Gas		Electronic	
	%	S.D.	%	S.D.	%	S.D.
Wrapped	24.79	±4.24	24.63	±4.24	27.14	±3.54
Unwrapped	20.12	±5.33	20.12	±3.81	32.58	±5.45

S.D. Standard Deviation

in Table 2 which presents data on moisture content of raw and cooked meat. The percentages of moisture content were lower in electronic- than in gas-cooked products, wrapped or unwrapped, and in electronically cooked, unwrapped products. The data agree with that presented by Kylen, et al. (1964) in the study of both pork and beef cooked by microwaves.

The largest percentage of weight loss occurred in pork cooked by electronic heat as seen in Figure 2 and Table 3. Although not significant, per cent losses of pork were higher when cooked unwrapped than wrapped.

The mean maximum temperature reached by pork roasts cooked by microwaves was 189 F after standing, compared with 169 F for the conventionally cooked roasts; therefore, excessive losses were expected. On an overall basis, differences of percentage weight loss, though comparatively small, were greatest in products prepared in cooking film, as seen in Table 4 and Figure 3.

TABLE 2

MEAN MOISTURE CONTENT OF RAW AND COOKED MEAT

Heat Source	Wrapped		Unwrapped	
	Raw %	Cooked %	Raw %	Cooked %
		Turkey		
Electric	61.7	63.3	70.7	64.7
Gas	54.3	67.7	68.0	58.0
Electronic	65.0	60.1	64.7	58.0
		Beef		
Electric	64.7	46.3	64.3	47.7
Gas	64.0	52.7	53.0	54.0
Electronic	62.7	44.0	54.7	44.3
		Pork		
Electric	65.7	45.3	65.0	62.3
Gas	65.7	49.0	64.7	43.7
Electronic	51.7	53.0	67.7	55.3

TABLE 3

MEAN PER CENT WEIGHT LOSS OF MEATS
COOKED BY THREE HEAT SOURCES

Meat	Heat Source					
	Electric		Gas		Electronic	
	%	S.D.	%	S.D.	%	S.D.
Turkey	21.19	±2.49	21.89	±3.03	21.76	±2.85
Beef	24.84	±5.80	23.84	±4.91	32.89	±3.55
Pork	21.34	±8.65	18.35	±4.15	34.93	±7.09

S.D. Standard Deviation

TABLE 4

MEAN PER CENT WEIGHT LOSS OF MEATS
COOKED WRAPPED OR UNWRAPPED

Covering	Meat					
	Turkey		Beef		Pork	
	%	S.D.	%	S.D.	%	S.D.
Wrapped	22.20	±2.87	28.75	±4.44	25.60	±6.44
Unwrapped	21.02	±2.71	25.63	±5.08	24.14	±6.81

S.D. Standard Deviation

Mean Percent Weight Loss of Meats Cooked With Varying Heat Source and Covering

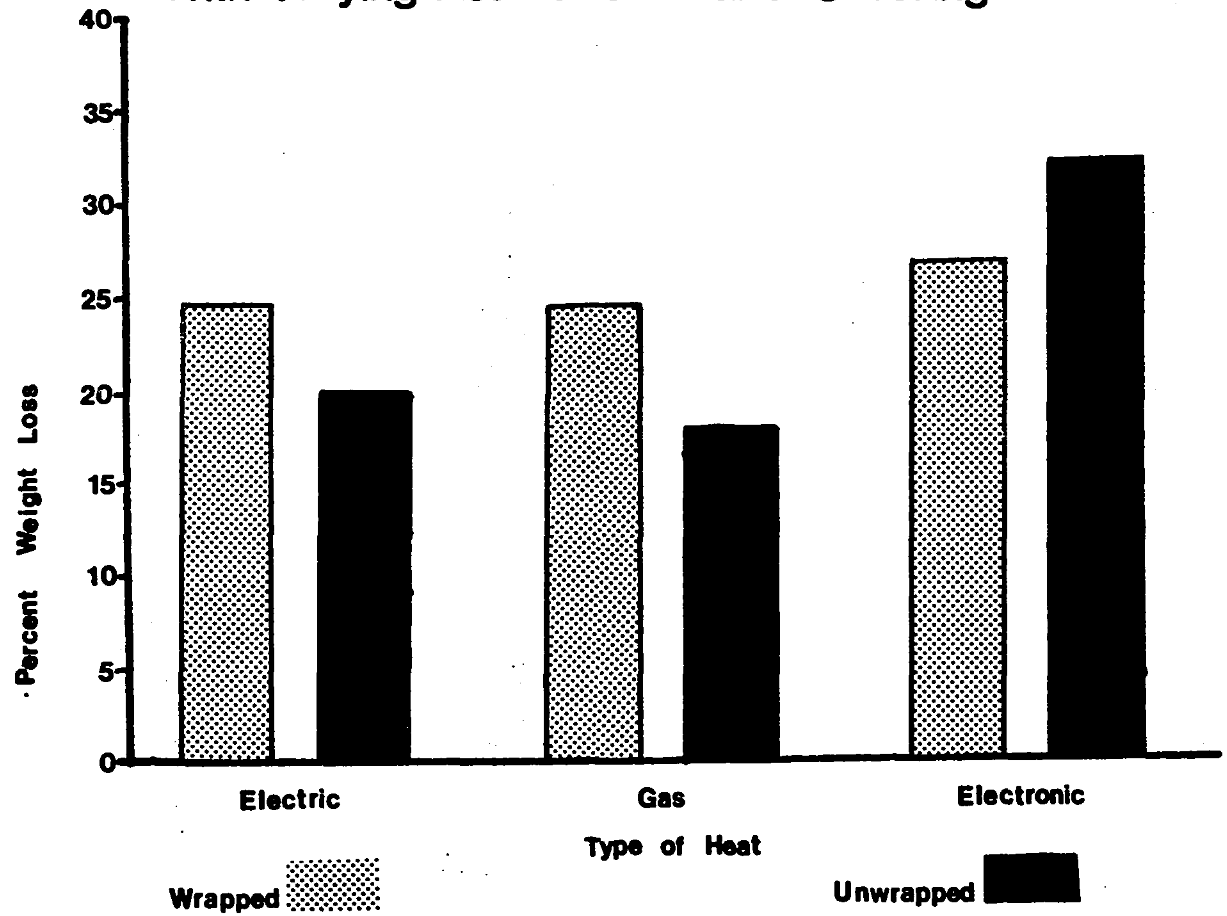

Figure 1

Mean Percent Weight Loss of Meats
Cooked With Three Heat Sources

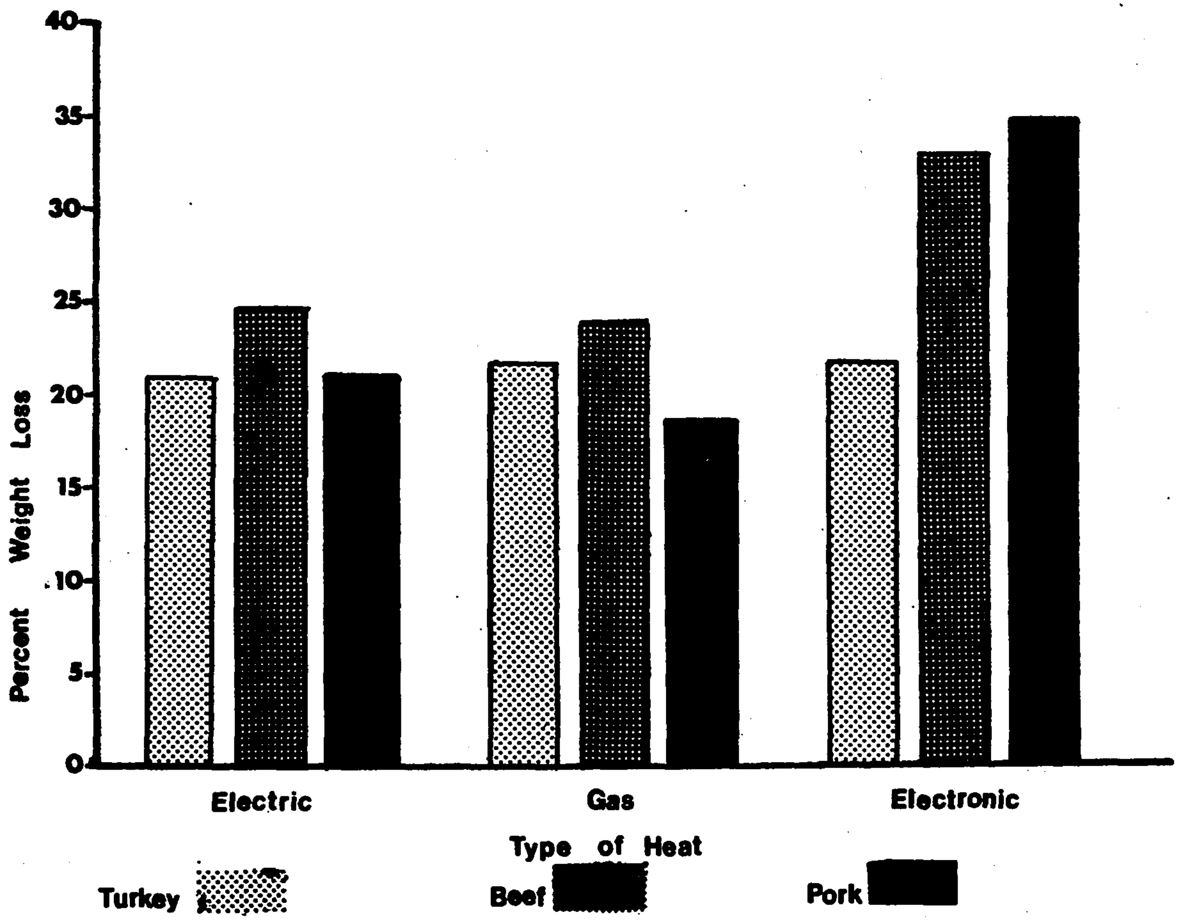

Figure 2

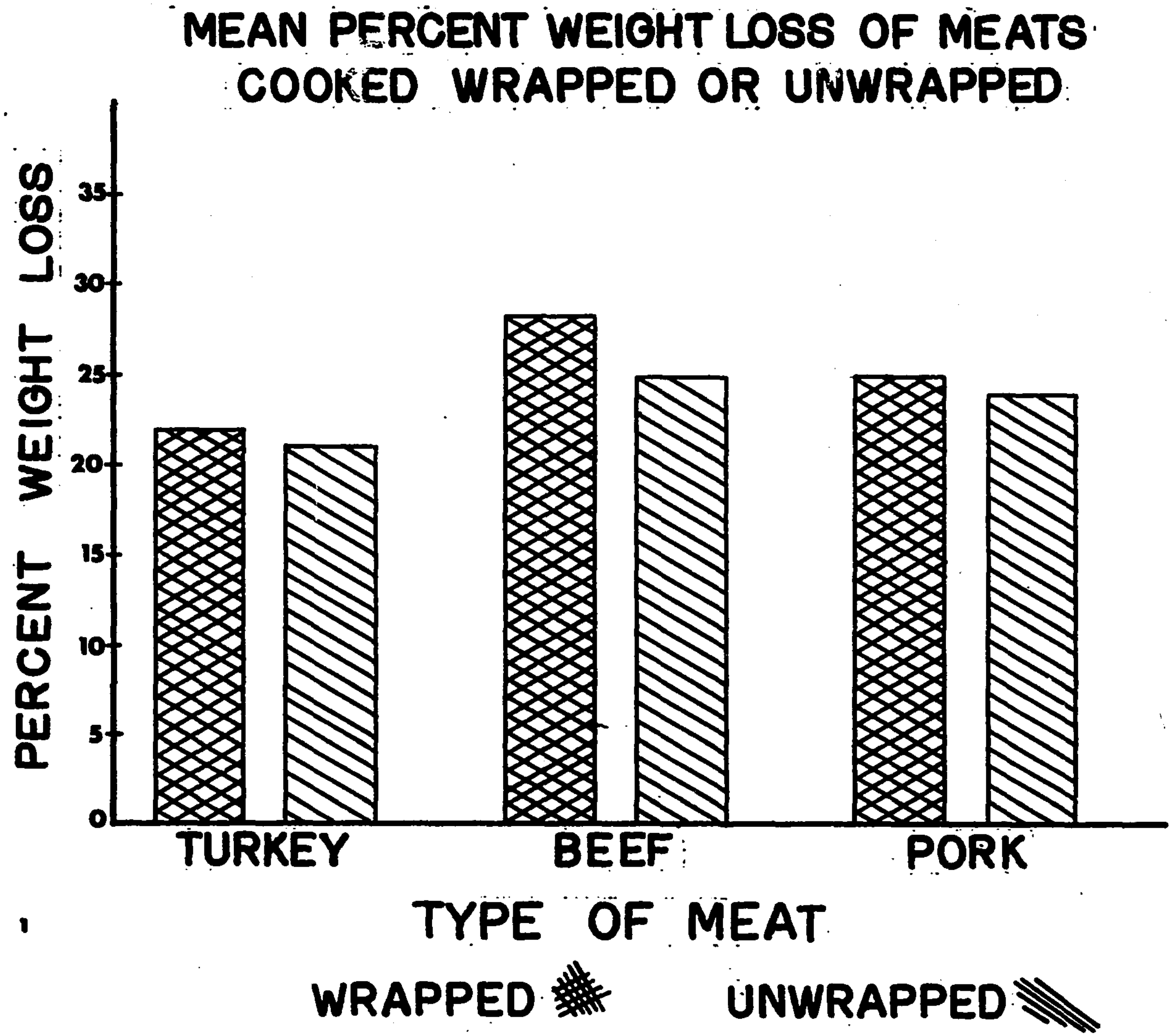
MEAN PERCENT WEIGHT LOSS OF MEATS COOKED WRAPPED OR UNWRAPPED
PERCENT WEIGHT LOSS
0
5
10
15
20
25
30
35
TURKEY
BEEF
PORK
TYPE OF MEAT
WRAPPED
UNWRAPPED

FIGURE 3

Losses were greatest in beef pot roasts, both in the cooking film and uncovered. However, as previously shown in Table 4, beef roast losses exceeded turkey or pork only for conventional cooking methods. These findings support research of Ruyack and Paul (1972) who compared microwave and conventional cooking of beef, using a plastic wrap. They found that cooking losses were increased by the use of the polyester wrap in both cooking procedures. They also stated that the volatile losses were only slightly smaller in the microwave oven for roasts in plastic wrap than for the uncovered roasts, due to evaporation loss through the holes in the film.

Nutrient Retention

The percentages of thiamine and riboflavin retained in the meats were calculated on the basis of the vitamin content of the roasts and/or breasts before and after cooking. Those for the different meats were also subjected to analysis of variance. The mean thiamine and riboflavin contents of the various meats, wrapped and unwrapped, are given in Tables 5 and 6. Although thiamine values are higher than those reported in the literature for reasonably comparable cuts, riboflavin values are within ranges reported (Watt and Merrill, 1963).

The mean percentages of thiamine and riboflavin retained in the edible portion of the various meats after

TABLE 5

THIAMINE CONTENT IN RAW AND COOKED MEAT, WRAPPED AND UNWRAPPED

Heat Source	Wrapped*			Unwrapped*		
	Raw mg/100 gm	Cooked mg/100 gm	Retention %	Raw mg/100 gm	Cooked mg/100 gm	Retention %
Turkey						
Electric	.63	.74	117	.60	.66	115
Gas	.49	.64	131	.43	.67	154
Electronic	.32	.51	159	.54	.51	91
Beef						
Electric	1.06	.22	21	1.18	.48	38
Gas	.93	.41	44	.72	.65	90
Electronic	.92	.34	37	.66	.27	43
Pork						
Electric	7.97	5.57	70	5.28	8.33	169
Gas	6.35	7.31	115	4.90	8.21	167
Electronic	3.27	8.84	270	5.63	7.16	143

* Each Figure is the Mean of 18 Determinations

TABLE 6

RIBOFLAVIN CONTENT IN RAW AND COOKED MEAT, WRAPPED AND UNWRAPPED

Heat Source	Wrapped*			Unwrapped*		
	Raw mg/100 gm.	Cooked mg/100 gm.	Retention %	Raw mg/100 gm.	Cooked mg/100 gm.	Retention %
Turkey						
Electric	.28	.18	63	.33	.23	64
Gas	.25	.21	84	.31	.15	47
Electronic	.20	.16	78	.25	.16	61
Beef						
Electric	.24	.21	88	.32	.23	73
Gas	.28	.18	64	.29	.38	131
Electronic	.28	.15	54	.20	.16	83
Pork						
Electric	.71	.38	54	.36	.43	109
Gas	.48	.30	63	.41	.21	52
Electronic	.38	.31	81	.59	.44	71

* Each Figure is the Mean of 18 Determinations

roasting are also included in Tables 5 and 6. For the beef pot roasts neither thiamine nor riboflavin retention was significantly higher when cooked unwrapped than when cooked in oven film. Average thiamine retention in beef was 45.5 per cent; for riboflavin, average retention was 85 per cent. Values for retention of both nutrients in turkey breasts and pork roasts were higher. There were no significant differences, however, when either meat was cooked wrapped or unwrapped. No variation was found in the retention of riboflavin but significantly higher amounts of thiamine were retained in pork. This was anticipated as pork is an outstanding source of thiamine in the diet.

Noble (1965) also had reported significant differences of thiamine retention in pork cuts with no variation for riboflavin values in the same meat. Unlike Kylen, et al. (1964) and Thomas, et al. (1949), this researcher cannot report lower retentions of thiamine after cooking meats in an electronic range than after cooking conventionally. The mean total percentage retentions of either thiamine or riboflavin were not significantly different for meats cooked by any of the three methods. Similarily, Apgar, et al. (1959) reported no significant difference in thiamine retention in longissimus dorsi muscle pork roasts due to conventional or electronic cooking. Bowers and Fryer (1972) reported that oven type (microwave or gas) did not affect riboflavin retention values in paired turkey pectoralis major muscles. Muscles heated by gas retained more riboflavin than did muscles heated by microwaves but differences were not significant.

Two theories related to the high retention of nutrients in cooked meats are that shorter cooking cycles effect higher retentions and that there is wide variance of the nutrient content in meat muscle. Tucker, Hinman and Halliday (1946) working with fried, broiled and braised beef attributed higher nutrient retentions in fried steaks to the shorter cooking times. Cover and Smith (1950) report similar findings with thiamine retentions higher in the meat of broiled than in the meat of braised steaks. In earlier work, Cover, McLaren and Pearson (1944) obtained higher thiamine retention in rare than in well-done roasts. The cooking time was shorter for the rare than for the well-done roasts. Hood, et al. (1955) found no significant difference in thiamine retention between moist and dry heat methods in either thick or thin cuts, although the cooking times were shorter for the moist heat methods.

In 1960, Noble and Gomez reported that longer heating (with higher temperature) did not affect the thiamine retention in the roasted meats. The differences in riboflavin retention were due to the use of different cuts of beef rather than to temperatures. As previously noted, cooking methods, cooking time, and internal temperatures did not significantly affect nutrient retention in the study presently being reported.

McIntire, et al. (1943); Brady, et al. (1944); and Meyer, et al. (1963) found that cooked values of nutrients exhibit large variations; in some specific cases, the nutrient content actually increased during cooking. Meyer, et al. (1963) further report that their data support the findings of Hinman, et al. (1946) that during heating, riboflavin was released from some precursor. This precursor could not be liberated under acid hydrolysis, as part of the fluorometric method of determination. Brady, et al. (1944) summarized their research by saying that

> . . . the need for standardized sampling techniques in studies of the riboflavin and thiamine contents of pork products is indicated in view of the significant differences in the vitamin content of different muscles as well as in different sections of the same muscle.

Shear Force

Force required to shear is believed to give some estimate of the ease or difficulty of chewing. A comparison of average shear values on the basis of cooking method and covering is shown in Table 7. Although no significant difference in shear values of meats due to cooking method was found, the meats cooked in an electric oven, wrapped in cooking film, had the lowest values. In addition, when considering type of heat, type of meat, and covering, the

TABLE 7

MEAN SHEAR VALUES OF MEATS IN POUNDS

Heat	Wrapped S.V.	Wrapped S.D.	Unwrapped S.V.	Unwrapped S.D.
		Turkey		
Electric	4.60	± .56	4.94	±1.64
Gas	3.60	± .78	5.24	± .79
Electronic	5.62	±1.77	4.44	±1.02
		Beef		
Electric	5.46	±1.40	5.16	±1.23
Gas	6.24	±2.20	6.06	±2.83
Electronic	5.26	± .91	5.92	±2.44
		Pork		
Electric	4.22	±1.39	4.80	±1.56
Gas	5.36	± .79	4.70	± .67
Electronic	4.38	±2.21	5.68	± .64

S.D. Standard Deviation
S.V. Shear Value

lowest shear values were obtained from meats cooked in the cooking film. However, these differences are not significant.

A condition of data scatter, as termed by Tuomy, was apparent in this research. Cores taken from the less exercised medial position were noticeably lower in shear value than cores from the more exercised lateral or dorsal positions. Results of this study suggested therefore, that shear force values will be lowest in muscles least exercised regardless of cooking method.

Tuomy, et al. (1963) made a similar statement from their investigation when they said that

> . . . neither total cooking time nor heating are factors in the tenderness of beef cooked to temperatures of less than 180 F. In that case, only the temperature attained and the inherent tenderness of the meat itself determine the final tenderness.

CHAPTER V

SUMMARY AND CONCLUSIONS

During preliminary investigations, the performance of six cooking films was compared and several factors were observed. Tenderness and palatability increased in products prepared in films whereas cooking times decreased. The Brown-n-Bag$_{TM}$ performed most acceptably in an electronic oven and less juices were lost from products prepared in this cooking film than all other films tested. Further work suggested by the preliminary study was related to methods of increasing the palatability of the products and determining nutrient retention.

The purpose of this current research, therefore, was to investigate the effect of roasting by electric, gas, or electronic heat on selected meat products for the following parameters: weight loss, thiamine and riboflavin retention, and shear force values. Hypotheses were made that there would be significant differences in these factors when cooking the products uncovered and in the Brown-n-Bag$_{TM}$ film.

Thirty retail cuts, weighing from 3-5 pounds each of beef pot roasts, turkey breasts, and pork loin were prepared; three by each heating method, both wrapped and unwrapped. Five replications of each cooking method were made. One hundred gram samples of all raw meats were frozen for further nutrient and moisture content analysis. Internal temperatures of 165 F were reached for beef roasts and turkey breasts; 170 F was reached for pork roasts.

Moisture content of all raw and cooked meat samples was determined from the weight difference of a 2 gm. trimmed portion before and after drying for 48 hours at 140 F. Thiamine and riboflavin were determined by the modified fluorometric methods of Conner and Straub (1941) and Peterson, Brady, and Shaw (1943), respectively. For tenderness determination, shear force values were recorded from cores taken in three anatomical positions of a cooked sample of each meat. Shearing of the cores was performed using a Warner-Bratzler shear machine. Statistical analysis of the data was computed through a TSAR Fortran computer program for three-way analysis of variance using F ratios.

It was found that conventional cooking required five times the cooking time of electronic cooking. Wrapping of meats increased cooking losses with conventional ovens; however, losses from meats cooked by electronic heat, unwrapped, were significantly higher than in the other heats. The largest percentage of weight loss occurred in pork cooked by electronic heat. There was no difference in the pork cooked wrapped or unwrapped.

Thiamine and riboflavin retention of the cooked meats did not vary significantly when cooked wrapped or unwrapped.

However, thiamine retention was significantly higher in pork than other meats. No significant variations were reported for riboflavin retention by any method for any meat.

Meats cooked in an electric oven, wrapped in cooking film, had the lowest shear force values. Cores for shearing taken from the medial position of a sample of cooked meat differed from cores taken in the dorsal or lateral positions. Medial position cores had lower shear force values than either of the other two positions.

Under the conditions of this study, the following conclusions can be made:

1. Meats roasted in conventional ovens, wrapped in an oven-proof cooking film, have increased weight losses.

2. Microwave cooking of meats unwrapped results in the greatest cooking losses.

3. Thiamine retention is significantly higher in pork than in beef or turkey products.

4. There is no significant difference between the retention of thiamine and riboflavin in meats cooked wrapped or unwrapped.

5. There are no significant variations in riboflavin retention for any parameter studied.

6. Shear force values are similar for all types of meats, sources of heat, and methods of cooking but tend to be lowest when cooked by electric heat, wrapped in an oven film.

Additional research relating the use of cooking films to nutrient retention in meats and/or other foods is suggested. Further research should be conducted on more than one cut of each kind of meat because in this study, only roasts were included.

Another investigation should involve the sensory measurement of tenderness in the cooked products for comparison with the objective shear force measurement. Other palatability factors of juiciness and flavor could be observed as well as tenderness.

The cooking film used in this study was the Brown-n-Bag$_{TM}$, size 17 by 22 inches. Other available consumer varieties of cooking film should also be studied to determine, for example, any differences in nutrient retention. Variations in film sizes do not seem important enough to merit further investigation.

In an attempt to prevent nutrient retentions in cooked products from rising to over 100 per cent, it is suggested that analyses also be made on a fat-free basis to control the inate variable of fat composition. Since there was wide variation in nutrient retention, control could better be assured also by the use of homogenates from the entire sample rather than specific 100 gm. portions.

Finally, the researcher recommends that the retention of additional nutrients be studied as cooking films have been suggested for uses other than for meat cookery.

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APPENDIX A

DATA SHEET FOR COOKING PROCEDURES

FORMULAS USED FOR RIBOFLAVIN AND THIAMINE DETERMINATIONS

DATA SHEET FOR COOKING PROCEDURES

Test Number__________ Chart Number__________ Date______

Item (Meat or Recipe)________________ Grade (Meat)_____

Width or Size of Film_______________ Film Supplier______

Flour Procedure______________________________________

Wrapping Technique__________________ Type Tie__________

Venting Procedure___________________

Description of Pan: Type____________ Pan Size__________

Type of Oven______________ Oven Temp. Setting___ Cycle___

Position of Item or Items in Oven_______________________

Starting Weight (Raw)________________

Cooked Meat Weight____________ Time of Weighing (After Removal from Oven)________

Weight of Drippings___________

Drippings Volume (Fat and Juice) ________

Fat Volume (After Settling) ________

Meat Juice Volume (After Settling) ________

Weight Loss % $\frac{\text{(Raw Meat-Cooked Meat}}{\text{Raw Meat}} \times 100)$ ______________

Time into Oven________ Starting Internal Temp. of Meat_____

Time Out Oven_________ Internal Temp. of Meat Upon Removal from Oven____________

Cooking Time (In Oven)____________

Final Interior Temp. of Meat____ F. After Holding (Outside Oven) ____Min. @____ F.

Appearance of Meat Before Slicing____________________

Appearance of Sliced Meat__________________________

Texture____

Appearance of Drippings___________________________

Condition of Film_________________________________

Remarks and Other Observations_____________________

FORMULAS USED FOR RIBOFLAVIN AND THIAMINE DETERMINATIONS

Riboflavin Determination

$$\text{mcg. riboflavin per 100 gm. of meat} = \frac{\text{tubes A - C}}{\text{tubes B-A}} \times \frac{\text{riboflavin increment}}{\text{5-ml. aliquot}}$$

$$\times \text{ ml. of original extract} \times \frac{100}{\text{sample weight}}$$

where A = reading on fluorometer of tube A

B = reading on fluorometer of tube B

C = blank of filtrate

Thiamine Determination

$$\text{mcg. thiamine per 100 gm. of meat} = (\text{Sample Reading} - \text{Blank Reading}) \times K \times \text{Dilution Factor} \times \frac{100}{\text{sample weight}}$$

where K = mcg. thiamine per increment on a scale reading

$$\text{dilution factor} = \frac{\text{initial vol.}}{\text{aliquot on column}}$$

$$\times \frac{\text{50 ml. eluate}}{\text{5 ml. in reaction vessel}}$$

APPENDIX B

ANALYSIS OF VARIANCE

TABLE 1

ANALYSIS OF VARIANCE OF WEIGHT LOSS AND TYPES OF HEAT, TYPES OF MEAT, AND METHOD OF COVERING

Source	DF	SS	MS	F-Ratio
Types of Heat	2	1282.066	641.033	23.46**
Types of Meat	2	471.441	235.720	8.62**
Covering	1	83.117	83.117	
Meat x Heat	4	773.361	193.340	7.07**
Meat x Covering	2	16.430	8.215	
Heat x Covering	2	622.041	311.021	11.38**
Meat x Heat x Covering	4	90.415	22.604	
Within Treatments	72	1966.754	27.316	

** Significance ($\underline{p} \leq 0.01$)

TABLE 2

ANALYSIS OF VARIANCE, THIAMINE RETENTION

Source	DF	SS	MS	F-Ratio
Kinds of Heat	2	1.19.2	0.5956	
Kinds of Meat	2	11.4794	5.7397	13.34**
Wrapping	1	0.0029	0.0029	
Meat x Heat	4	2.0613	0.5153	
Meat x Wrapping	2	0.7011	0.3506	
Heat x Wrapping	2	2.7709	1.3854	
Meat x Heat x Wrapping	4	2.0067	0.5017	
Within Treatment	35	15.1659	0.4333	

** $p \leq 0.01$

TABLE 3

ANALYSIS OF VARIANCE, RIBOFLAVIN RETENTION

Source	DF	SS	MS
Kinds of Heat	2	0.0812	0.0406
Kinds of Meat	2	0.1046	0.0523
Wrapping	1	0.0253	0.0253
Meat x Heat	4	0.6388	0.1597
Meat x Wrapping	2	1.2734	0.6367
Heat x Wrapping	2	0.2714	0.1357
Meat x Heat x Wrapping	4	1.3679	0.3420
Within Treatment	35	7.2939	0.2084

TABLE 4

ANALYSIS OF VARIANCE, SHEAR FORCE VALUES

Source	DS	SS	MS
Kind of Heat	2	2.3846	1.1923
Kind of Meat	2	15.8687	7.9343
Wrapping	1	1.3444	1.3444
Meat x Heat	4	4.9507	1.2377
Meat x Wrapping	2	0.4562	0.2281
Heat x Wrapping	2	0.0162	0.0081
Meat x Heat x Wrapping	4	16.2271	4.0568
Within Treatment	72	168.8880	

APPENDIX C

COMPILATION OF THIAMINE AND RIBOFLAVIN CONTENT IN RAW AND COOKED MEATS

COMPILATION OF MEAN SHEAR FORCE VALUES

TABLE 1

NUTRIENT CONTENT IN TURKEY BREASTS*

Covering	Thiamine Raw (mcg./gm.)	Thiamine Cooked (mcg./gm.)	Riboflavin Raw (mcg./gm.)	Riboflavin Cooked (mcg./gm.)
		Electric		
U	5.67	8.75	3.18	1.40
U	8.13	5.60	2.78	2.38
U	4.42	5.41	4.76	2.93
W	5.92	6.73	2.74	1.47
W	10.00	7.89	2.98	1.32
W	3.18	7.63	2.72	2.61
		Gas		
U	4.10	4.44	3.63	1.96
U	4.13	5.68	2.78	1.22
U	4.72	10.14	3.16	1.34
W	2.57	4.94	0.63	2.14
W	7.47	7.30	2.19	1.55
W	4.77	7.09	4.84	2.60
		Electronic		
U	4.72	10.14	3.16	1.34
U	6.48	4.00	2.10	1.11
U	5.29	6.00	3.12	2.85
W	2.00	6.02	1.08	1.04
W	2.46	2.46	2.53	1.71
W	4.77	7.09	4.84	2.60

U - unwrapped
W - wrapped
* all values determined on dry weight basis

TABLE 2

NUTRIENT CONTENT IN BEEF POT ROASTS*

Covering	Thiamine Raw (mcg./gm.)	Thiamine Cooked (mcg./gm.)	Riboflavin Raw (mcg./gm.)	Riboflavin Cooked (mcg./gm.)
		Electric		
U	14.85	4.90	3.18	2.80
U	13.55	7.86	4.03	2.19
U	7.26	1.76	2.58	2.02
W	16.61	1.70	2.79	1.77
W	8.18	3.03	2.05	1.40
W	7.06	2.08	2.68	3.26
		Gas		
U	10.15	3.32	3.16	3.34
U	5.39	8.36	2.16	1.91
U	9.11	4.86	3.64	5.63
W	14.03	2.57	2.37	1.61
W	6.55	8.14	2.65	1.62
W	7.54	1.89	3.57	2.22
		Electronic		
U	8.67	3.05	1.94	1.10
U	7.71	3.46	2.61	1.65
U	3.69	1.77	1.63	2.10
W	11.76	2.89	1.99	1.50
W	7.35	5.78	2.58	2.04
W	8.50	1.72	4.07	1.06

U - unwrapped
W - wrapped
* all values determined on dry weight basis

TABLE 3

NUTRIENT CONTENT IN PORK LOIN ROASTS*

Covering	Thiamine Raw	Thiamine Cooked	Riboflavin Raw	Riboflavin Cooked
	mcg./gm.		mcg./gm.	
		Electric		
U	69.08	75.66	4.19	6.86
U	42.64	117.65	3.61	3.15
U	46.97	56.71	3.25	2.92
W	112.90	51.83	10.50	5.75
W	80.65	80.36	7.88	4.03
W	46.65	35.07	3.18	1.83
		Gas		
U	65.44	118.06	6.38	3.30
U	36.43	80.36	3.26	1.61
U	46.97	56.71	3.25	2.92
W	54.05	95.74	4.14	2.55
W	75.00	79.10	5.97	4.07
W	61.46	44.64	4.52	2.55
		Electronic		
U	65.97	84.18	4.26	2.24
U	36.70	85.37	7.00	7.94
U	66.25	45.45	6.51	3.13
W	38.13	99.43	3.38	2.18
W	29.71	125.00	3.52	2.68
W	30.32	40.79	4.52	4.57

U - unwrapped
W - wrapped
* all values determined on dry weight basis

TABLE 4

MEAN SHEAR FORCE VALUES (IN LBS.) OF COOKED PRODUCTS

Turkey		Beef		Pork	
W	U	W	U	W	U
		Electric			
5.3	5.6	4.7	6.1	2.7	4.0
3.9	4.5	7.4	3.2	3.3	6.3
4.3	2.7	6.4	5.2	4.7	5.2
		Gas			
3.5	4.3	9.4	4.5	5.1	3.8
3.0	5.6	7.7	4.8	6.7	5.3
3.6	4.5	4.5	5.3	5.2	4.9
		Electronic			
8.4	6.2	6.3	3.3	3.8	6.6
6.1	3.6	4.6	7.1	8.0	4.8
5.0	3.9	6.2	9.4	2.0	5.6

W - wrapped
U - unwrapped