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Moisture and Microwave Effects on Selected Characteristics of Turkey *Pectoral* Muscles

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To the Graduate Council:

I am submitting herewith a thesis written by Georgia Mae Williams entitled "Moisture and Microwave Effects on Selected Characteristics of Turkey *Pectoral* Muscles." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

Grace E. Goertz, Major Professor

We have read this thesis and recommend its acceptance:

Ada Marie Campbell, Jimmie L. Collins

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

October 9, 1970

To the Graduate Council:

I am submitting herewith a thesis written by Georgia Mae Williams entitled "Moisture and Microwave Effects on Selected Characteristics of Turkey Pectoral Muscles." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science.

Major Professor

We have read this thesis and recommend its acceptance:

Ada Marie Campbell

Jessie L. Collins

Accepted for the Council:

Vice Chancellor for
Graduate Studies and Research

MOISTURE AND MICROWAVE EFFECTS ON SELECTED CHARACTERISTICS OF TURKEY PECTORAL MUSCLES

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Georgia Mae Williams

December 1970

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ABSTRACT

The effect of added water and microwave heating on several characteristics of ground composites of pectoral muscles of eight USDA Grade A turkey toms was investigated. Samples (200 g) containing 0, 15, or 30 ml added water were prepared and heated in a Raytheon Mark IV Radarange (2450 MHz) for 0, 70, and 130 sec. Water added in the amounts of 15 or 30 ml represented 7 or 13% of the sample weight prior to heating.

Expressible moisture index and total moisture decreased with increased cooking times, whereas fat-free dry weight and initial and total cooking losses increased with cooking. Extractable fat and pH tended to increase when comparing raw and cooked samples.

Increasing the water levels in the samples resulted in decreased values for expressible moisture index and fat-free dry weight. Total moisture and initial and total cooking losses increased as the level of added water was increased. The effects of added water on extractable fat and pH were not consistent.

Expressible moisture index seemed to be the best measure of treatment effects since a greater percentage variation attributable to treatment was observed for this measurement than for the measurements of cooking losses and total moisture. Although water was lost during cooking, as indicated by total moisture values, it was possible to retain some added water. Cooking time contributed the greatest percentage variation, but added water also had significant effects on all the

characteristics studied. The rate of microwave heating did not seem to be affected by the addition of water. This might be attributed to the maintenance of a constant water load within the oven.

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CHAPTER I

INTRODUCTION

Muscle is a complex biological system composed of water, proteins, fats, minerals, and carbohydrates. Although affected by proximate chemical composition, muscle characteristics also are influenced by the molecular, microscopic, and macroscopic structural organization (Paul, 1964). The ability of meat to retain moisture during cooking is an important property of muscle. During heating the relative proportions of water, protein, and fat are altered.

Muscle proteins may be divided into intracellular (protoplasmic) proteins which consist primarily of actin and myosin and extracellular (structural) proteins which are mostly collagen and elastin (Lowe, 1955). Protein chemically and physically holds water within muscle. Factors which affect the chemical and physical composition of protein also affect water in ways that alter the juiciness, tenderness, and overall acceptability of meat. Heating meat denatures protein and decreases the ability of muscle to retain water. Working with tube-cooked beef, Wierbicki et al. (1957) noted that heat denaturation of muscle protein began at 40°C and essentially was completed at 70°C. Water retention in turkey pectoralis major muscle cooked by dry heat decreased as end point temperatures increased from 10° to 65°C (Rogers et al., 1967). Heat-induced changes in proteins result in shrinkage of tissue and release of juice (Hamm, 1966) with accompanying changes in tenderness and pH (Paul, 1964).

Heat can be applied in three basic ways: conduction, convection, and radiation. Both broiling and microwave cookery occur through radiation and conduction. Electrical or gas broiling takes place at low frequencies of 60 Hz, whereas microwave heating is at higher frequencies. The most commonly used frequencies are 915 and 2450 MHz (Goldblith, 1966). The presence of polar molecules in food affects the manner in which the food responds to microwave heating. Little is known concerning the effects of microwave heating for different lengths of time on the components of meat. Therefore, it was the purpose of this research to study the effects of added water and microwave heating on several characteristics of turkey pectoral muscles.

CHAPTER II

REVIEW OF LITERATURE

I. EFFECTS OF HEATING ON MUSCLE PROTEIN

Heating alters the chemical and physical characteristics of muscle protein and causes denaturation. However, protein denaturation caused only by thermal means occurs rarely, since the effects of pH are so closely related to those caused by heating (Joly, 1965).

The effects of heat denaturation on muscle protein were summarized by Hamm (1966). Heating beef from 20° to 30°C resulted in no changes in the colloidal-chemical properties of the tissue or in the solubility or ion-binding of muscle protein. As temperature was increased from 30° to 40°C, mild denaturation occurred resulting in the unfolding of peptide chains and the formation of new salt and/or hydrogen bonds. Hydration was increased slightly in the acidic range from the isoelectric point. Strong denaturation of myofibrillar protein occurred between 40° and 50°C. With increased temperature, protein solubility and acidic groups decreased, whereas hydration, rigidity, and pH increased. Disappearance of carboxyl groups was the criterion for determining changes in hydration. The reaction causing decreased carboxyl groups did not seem to form many new cross linkages between peptide chains since water holding capacity did not decrease at pH 4.5. At pH values higher than the isoelectric point, negative protein charges decreased with a corresponding decrease of

electrostatic repulsion between peptide chains. This resulted in decreased water holding capacity and a tighter protein network. At pH values below the isoelectric point a decrease in negative protein charges caused salt cross linkages to break resulting in loosened protein structure and elevated water holding capacity. A small portion of the sarcoplasmic proteins also was denatured between 40° and 50°C.

Stable cross linkages were formed between 50° and 55°C that could not be split by adding base or acid in the pH range of 3.0 to 8.0. Probably the new linkages were disulfide bonds and perhaps some ester bonds. Since there was no significant decrease in basic groups, it was doubtful that new peptide bonds were formed. Rearrangement of myofibrillar proteins at these temperatures caused a delay in changes of water holding capacity and pH.

At 65°C most fibrillar and globular muscle proteins were coagulated. Collagen shrinkage occurred at temperatures around 63°C. Between 40° and 70°C, Wierbicki et al. (1957) noted the occurrence of dynamic shifts involving potassium, calcium, and magnesium that promoted hydration of meat protein. This tended to counteract the dehydration usually associated with heat denaturation. Possibly denaturation destroyed some free carboxyl and sulfhydryl groups of the protein.

At temperatures between 60° and 70°C loss of water holding capacity neared completion and peptide chains unfolded and meshed closely together. Collagen was converted to gelatin at temperatures above 80°C (Hamm, 1966). As end point temperature was increased from 68° to 85°C, Ritchey (1965) noted that meat became drier, harder, more mealy, and contained less

connective tissue, but muscle fragmentation was not changed. When muscle fibers were heated from room temperature to 80°C on the stage of a microscope, Hostetler et al. (1968) reported changes in fiber width attributable to heating that were closely related to changes in water holding capacity. Changes in fiber length were related to loss of acidic groups, coagulation of protein, and volume changes in cooked meat.

When chicken broilers were cooked to an internal temperature of approximately 85°C, Khan et al. (1965) reported destruction of about half of the proteolytic activity and buffer extractability of muscle protein. Cooking also resulted in a decreased amount of extractable nitrogen that was attributable to the loss of solubility of myofibrillar and sarcoplasmic proteins.

II. EFFECTS OF HEATING ON pH

Heating meat generally increases its pH. When pectoralis major muscles of turkeys were roasted to end point temperatures ranging from 10° to 65°C by Rogers et al. (1967), pH increased as end point was elevated. A total pH increase of 0.11 unit was observed. In the heating of beef, a significant change in pH did not occur until a temperature of 40°C was reached (Hamm et al., 1960). Between 40° and 50°C there was a marked elevation in pH followed by a slight drop between 50° and 55°C. Above 55°C pH increased with higher temperatures. Changes in water holding capacity followed a reversal of this pattern. As temperature was increased, water holding capacity decreased. However, between 50° and 55°C there was a slight increase in water holding capacity that might be related to the slight drop in pH also at 50° and 55°C.

Tube heating of beef resulted in rather uniform pH increases as meat was heated to 75° or 85°C. In samples containing 10% added water the pH increased from 5.58 at 30°C to 5.90 at 70°C (Wierbicki et al., 1957). Cooking chilled and aged pork muscles increased pH by about 0.34 unit (Kauffman et al., 1964).

The pH changes that occur during heating were suggested by Hamm (1966) to be caused by changes in charge and/or hydrogen bonding within the myofibrillar proteins. Bendall et al. (1962) reported that washed pork fibrils consisting mainly of actomyosin exhibited an upward pH shift to 6.0 when heat-coagulated in isotonic KCl at pH 5.4. This represented the binding of about 12 protons/100,000 g of protein or a pH rise of about 0.3 unit in intact meat with all its natural buffers present. The release of tyrosyl hydroxyl groups and changes in pK values were considered responsible for shifts in pH of denatured egg protein (Bendall, 1964). Changes in pK values were attributed to the new configuration of the denatured protein and the formation of charged groups formerly held apart in the helical portions of the native protein. It was suggested that this also might occur during the heat denaturation of actomyosin.

III. EFFECTS OF HEATING ON FAT

Ether extractable material in meat usually increases from the raw to the cooked state even when data are converted to the dry basis to allow for water loss during heating (Paul, 1964). Satorius et al. (1938) reported an increase in ether extractable materials of several beef muscles cooked to end point temperatures of 58°, 67°, and 75°C when calculated on

either a wet or dry basis. A possible explanation for the increased extractable fat is that heat may alter muscle structure so as to make fatty materials present in raw muscle more readily extractable by ether (Paul, 1964). Working with ground beef cylinders, Irmiter et al. (1967) noted an increase in extractable fat (wet basis) from 2% in the raw to 5% in the sample cooked to 80°C.

Percentage of extractable fat in cooked longissimus dorsi and biceps femorus muscles increased as the percentage of moisture was decreased. However, when calculated on a dry weight basis the amount of fat was relatively constant (Ritchey, 1965). In contrast, microscopic examination of meat indicated that fat was lost from beef muscles during cooking. The fat tended to migrate from structurally undamaged cells to surrounding spaces. Droplets of dispersed fat became smaller as the distance increased from the source to the periphery of the area examined (Wang et al., 1954). Hoke et al. (1968) reported that stewed poultry breast muscles had a greater percentage of extractable fat than those roasted.

IV. EFFECTS OF HEATING ON TOTAL MOISTURE

It is generally accepted that the total moisture of meat decreases during cooking. Satorius et al. (1938) cooked beef semitendinosus muscles to end point temperatures of 58°, 67°, and 75°C and observed that total moisture as measured by drying under reduced pressure decreased as internal temperature increased from 58° and 67°C to 75°C. However, no difference in total moisture was observed between 58° and 67°C. It was

suggested that this water loss might be attributed to changes in the colloidal structure resulting from coagulation.

Rogers et al. (1967) studied the moisture changes in turkey breast and thigh-leg muscles resulting from dry heat cooking at 176°C to end point temperatures of 10°, 25°, 35°, 45°, 55°, and 65°C. Percentage total moisture was determined by air and in vacuo drying. As measured in vacuo, total moisture in the pectoralis major muscles decreased from 74.33% in the uncooked (10°C) samples to 68.69% in the samples heated to 65°C. The greatest change in percentage total moisture occurred between the 10° and 25°C samples. Hoke et al. (1968) roasted fresh-unfrozen and stored-frozen male turkeys to end point temperatures of 74°, 79°, and 85°C. Total moisture for cooked muscles from fresh-unfrozen birds was significantly ($P < 0.01$) greater than that for frozen-stored, whereas total moisture was unaffected by varying storage times.

V. EFFECTS OF HEATING ON COOKING LOSSES

Losses occurring during meat cookery consist of both volatile and drip losses. Drip is composed of fat, water, salts, and both nitrogenous and non-nitrogenous extractives (Lowe, 1955). Water was the main component of cooking loss when beef steaks were heated to internal temperatures ranging from 61° to 80°C (Ritchey et al., 1964), whereas only 2% of the cooking losses was fat and other solids. These findings support the statement of Lowe (1955) that volatile losses were primarily the result of water evaporation but included certain volatile aromatics and decomposition products of fat and protein.

Total cooking losses generally increase as end point temperature and time are increased. Sanderson et al. (1963) cooked longissimus dorsi and semimembranosus muscles by moist heat to internal temperatures of 140°, 150°, and 176°F (60°, 66°, and 80°C) and reported an increase in cooking losses for both muscles with each increase in end point temperature. Goertz et al. (1964a) roasted defrosted turkeys on V-shaped racks to end point temperatures of 85° and 90°C in the breast muscle. Increased cooking losses were noted as cooking time in min/lb increased. In a study of the effect of cooking temperatures on broiler acceptability, Goertz et al. (1964b) cooked chicken halves by two methods. Cooking in a broiling compartment at increasing temperatures of 350°, 375°, and 400°F (177°, 191°, and 204°C) to an end point of 203°F (95°C) resulted in a slight, although nonsignificant increase in total, volatile, and drip losses at all temperatures.

Total cooking losses of turkey breast muscle increased from 6 to 17% when end point temperature increased from 25° to 65°C (Rogers et al., 1967). With each 10° increment in end point temperature, losses were significantly different ($P < 0.05$) except between 35° and 45°C. The greatest increase in weight loss occurred between 55° and 65°C. Hoke et al. (1968) cooked turkeys to end point temperatures of 165°, 175°, and 185°F (74°, 80°, and 85°C) and reported significant differences ($P < 0.01$) in total cooking losses. Drip losses remained fairly constant with a mean value of 2.3%, whereas evaporative losses paralleled the changes noted in total cooking losses.

Monk et al. (1964) cooked 50 g portions of ground broiler muscle at 212°, 240°, and 250°F (100°, 116°, and 120°C) for 20, 10, and 5 min, respectively and by microwave for 60 sec. Samples were heat sealed in Mylar bags prior to cooking. Significantly higher ($P < 0.01$) cooking losses occurred at 250° than at 212°F. Electronic cooking resulted in significantly lower ($P < 0.01$) cooking losses than was observed when heating by all other methods.

VI. WATER HOLDING CAPACITY

The ability of muscle to retain water was reported by Hamm (1960) as an important characteristic of meat since it was closely related to taste, tenderness, color, and other features of meat quality. Hamm (1960) defined this water holding capacity as the ability of meat to hold fast its own or added water during the application of any force such as pressing, heating, chewing, or grinding.

In a review of meat hydration, Hamm (1960) noted that muscle proteins were mainly responsible for water-binding in meat. Tightly bound water represents 4 to 5% of the moisture and is held by hydrophilic groups in mono- and multimolecular layers between the peptide chains of the protein. The physical properties of the bound water differ from the remaining water by exhibiting lower vapor pressure, freezing point, and solvent power. This bound water which remains liquid at subfreezing temperatures covers the protein molecule in two layers distinguishable by changes in vapor pressure. A gradual decrease in liquid (bound) water was reported by Toledo et al. (1968) as temperatures were

lowered from 0°to -50°C also indicating that all bound water was not held with equal force.

Although no standard method has been developed for the determination of bound water, the term generally indicates water that is so closely held by the other components of the system that its properties deviate from the properties of the free or less tightly held water (Toledo et al., 1968). Using a nuclear magnetic resonance technique to determine the amount of liquid (bound) water in a complex colloidal system, Toledo et al. (1968) noted the same amount of liquid water in flour samples with different moisture contents when observed at specified sub-freezing temperatures. Therefore, they concluded that the amount of water bound by a given weight of dry matter was independent of the total moisture content. Hamm (1960) also indicated that bound water was not altered by structural or electrostatic changes in protein.

Water not tightly bound generally is considered as loose water. The mechanism by which loose water is held electrostatically was called the net charge effect by Hamm (1959). Peptide chains of protein molecules possess free electrical charges which result from the presence of negative carboxyl and positive amino groups. Also present are polar groups which attract the dipolar water molecules. However, since inter- and intramolecular salt linkages occur, only the net charge of the protein affects water holding capacity and this effect is minor. The spatial relationship of muscle protein also affects its hydration. Peptide chains are connected by cross-linkages such as those of salts, bivalent metals, sulfhydryl, or hydrogen bonds. As a result, a number of charged groups

are not available for water-binding because of insufficient space for the water molecules. When the cross linkages are cleaved, the peptide chains are more flexible and water is attached to polar groups. Usually this so-called stereo effect is accompanied by the net charge effect.

Water holding capacity generally decreases as temperature increases. However, in the temperature range between 50° and 55°C, Satorius et al. (1938) noted a marked delay in hydration changes (water holding capacity). Hamm et al. (1960) observed that this probably was attributed to a delayed decrease in acidic groups. In a study of the effect of cooking temperatures on the water holding capacity of ground loin, Wierbicki et al. (1957) concluded that reactions occurred between 55° and 65°C that counteracted the trend toward water loss by the proteins. Rogers et al. (1967) reported decreased water retention (greater loose water) in turkey pectoralis major muscle as end point temperature was increased with the exception that less water was retained at 45°C than at 55° or 65°C. The largest difference in moisture retention occurred between 35° and 45°C.

In a comparative study of the composition and properties of eight different bovine muscles, Swift et al. (1959) noted that water retention (water holding capacity) was related directly to the moisture-protein ratio. Although protein is primarily responsible for water-binding, water retention was related inversely to protein content. Increasing moisture-protein ratios were associated directly with increasing water retention which was accompanied by higher levels of fat.

VII. MICROWAVE HEATING

Microwaves are electromagnetic radiations with a frequency range of approximately 10^8 to 10^{10} MHz. These waves are generated by radio frequency power tubes from high voltage direct current (Copson, 1960). Frequencies of 915 and 2450 MHz are used most frequently for the heating of foodstuffs. Microwaves are emitted from a power or magnetron tube into the oven cavity where they initially heat food by a radiant process (Goldblith, 1966). Foodstuffs are penetrated by microwaves, thus causing heating to begin as the dipolar molecules in food attempt to align with the electromagnetic field of alternating current. The friction produced by the motion of the food molecules generates heat which is conducted throughout the food.

This cookery method has been studied in relation to both domestic and industrial applications. Most studies reported have compared the effects of microwave and conventional methods of cooking and have noted that greater total cooking losses usually occur with heating by microwaves (Headley et al., 1960; Marshall, 1960). However, Phillips et al. (1960) found no significant difference in cooking losses of chicken cooked by conventional and microwave methods. Industrially, microwave energy has been combined with steam in the effective conveyorized cooking of chicken parts. This combination method prevented excessive cooking losses and lessened labor costs by shortening production time (Smith, 1969).

The effect of microwave energy upon a food is greatly influenced by its physical and chemical composition. Changes in a single component

can exert a profound influence on the relative dielectric loss factor of the food. Goldblith (1966) reported that the dielectric loss factor ($\varepsilon\gamma''$) is the overall measure of the ability of a food to respond to microwave energy.

The dielectric loss factor of egg albumin decreased with increased water dilution of protein. Consequently, during electronic cooking, greater energy was required in the diluted samples to attain a similar end point temperature. Thus dielectric loss factor was inversely related to water content (Baldwin et al., 1967). In a study of the effect of chemical composition on the dielectric loss factor of reconstituted ground beef, Van Dyke et al. (1969) found little increase in the dielectric value as water concentration increased from 1.8 to 20%. However, as the water level was raised from 20 to 45%, dielectric values increased dramatically. Beyond the 45% water level little alteration in dielectric loss factor was noted. An increased NaCl level increased dielectric loss value; the effect was more pronounced as water levels increased. An inverse relationship was observed between extractable fat and dielectric loss.

CHAPTER III

PROCEDURE

I. STUDY PLAN

The effects of three levels of added water and three microwave cooking times on water holding capacity as evaluated by expressible moisture index, total moisture, cooking losses, extractable fat, and pH of pectoral muscles from eight turkey toms were studied. A ground composite of the right and left pectoralis major and secundus muscles from each bird constituted the sample for a replication. Within a replication, nine 200 g samples, each containing 0, 15, or 30 ml added water, were cooked for 0, 70, or 130 sec according to the treatment plan (Cochran et al., 1957) presented in Table I. Water added in the amounts of 15 or 30 ml represented 7 or 13% of the sample weight prior to heating.

The data were assessed by analyses of variance according to the plan presented in Table II. Significant differences were located by Duncan's Multiple Range test. The percentages of variation attributable to treatments and error for expressible moisture index, total moisture, and initial and total cooking losses were determined from the components of variance based on the mean squares used in the analyses of variance (Li, 1964). These were not calculated for fat-free dry weight, extractable fat, and pH.

TABLE I

TREATMENT PLAN FOR GROUND TURKEY SAMPLES[1]

Added Water (ml)	Replication							
	I	II	III	IV	V	VI	VII	VIII
0								
Time (sec)								
0	5	5	6	7	1	4	3	3
70	4	1	2	8	2	7	1	1
130	9	3	3	2	9	8	8	8
15								
Time (sec)								
0	7	9	7	4	3	5	5	2
70	1	6	9	6	5	6	9	4
130	6	4	4	3	6	2	4	6
30								
Time (sec)								
0	8	7	8	1	7	1	2	5
70	3	2	1	9	4	3	6	7
130	2	8	5	5	8	9	7	9

[1]Arabic numerals within a replication indicate order in which samples were treated.

TABLE II

PLAN FOR ANALYSIS OF VARIANCE

Source of Variation		Degrees of Freedom
Total		143
Among birds		7
Within bird (error term)		136
Total treatment	64	
Added water	16	
Cooking time	16	
Interaction of water and cooking time	32	
Between duplicates (error term)	72	

II. MEAT SOURCE

Eight frozen USDA grade A turkey toms of the same brand, weight class (22 lb 8 oz to 23 lb 12 oz), and storage lot were purchased from McKenry Produce Company in Knoxville, Tennessee, and stored at -18°C in an institutional size freezer until needed for sampling.

III. PRELIMINARY STUDY

A preliminary study was conducted to determine the cooking time required to achieve a predetermined final end point temperature range in the midpoint of the 200 g samples and this was found to be 5 min following removal from the oven. The resulting temperature ranges were 7° to

10°C, 35° to 50°C, and 65° to 80°C, respectively, for the 0, 70, and 130 sec cooking periods.

The Raytheon Mark IV Radarange (2450 MHz) used in this investigation had adequate power output and fairly uniform cooking power distribution. Testing procedures outlined in the service manual were followed to determine power output. Reconstituted dehydrated egg whites were cooked by the method of Van Zante (1966) to check power distribution.

IV. SAMPLE PREPARATION

In preparation for sampling, the Cry-O-Vac packaged birds were defrosted in an institutional size refrigerator (3°C) for 24 hr followed by 24 hr at 23°C. After defrosting, the right and left pectoralis major and secundus muscles were removed and ground once using a grinding attachment (Form 10230) accompanying a Hobart mixer (model D-300T). The four muscles from a bird were ground together into pliofilm bags which were wrapped in heavy duty aluminum foil, and stored at -18°C until needed for sampling.

The ground muscles from a bird were defrosted (24 hr at 3°C) prior to cooking. Each of three 600 g portions was weighed into a mixing bowl into which 0, 45, or 90 ml distilled, demineralized water was added. Meat and water were blended 15 sec on speed 1 in a Kitchen Aid mixer (model 3-C) and refrigerated until needed. Following the plan for cooking (Table I, page 16), 200 g portions of the meat, containing either 0, 7, or 13% added water, were weighed into a cylindrical mold and shaped into patties 13 cm in diameter and 2.5 cm thick.

Prior to cooking, a spirit-filled thermometer was inserted horizontally into the midpoint of a patty which was cooked on a styrofoam rack in a 9 in. Pyrex dish. A constant water load within the oven was maintained by increasing the amount of water in a beaker as the percentage of water in the meat decreased. End point temperature was read immediately after heating for the specified time and following a 5 min interval. Data for cooking losses were determined from appropriate weights recorded before and after cooking.

V. WATER HOLDING CAPACITY, pH, TOTAL MOISTURE, EXTRACTABLE FAT, AND FAT-FREE DRY WEIGHT

The press method used to determine water holding capacity (EMI) was similar to that used by Rogers et al. (1967). Duplicate 0.500 ± 0.003 g portions (23°C) from the midpoint of the sample were weighed into polypropylene weighing bottles to prevent moisture loss. Each portion was transferred to the center of a 15 cm Whatman No. 50 filter paper. A unit, consisting of 2 pieces of filter paper and meat samples stacked alternately between three 6 x 6 in. Plexiglas plates, was pressed on a Harco hydraulic press at 15 psig[1] for 1 min. Following pressing, meat and exuded moisture rings on the filter paper were outlined with pencil and the areas measured with a Keuffel and Esser compensating polar planimeter until duplicate measurements agreed within 0.02 cm.

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[1] Unit pressure = $\frac{\text{total force}}{\text{unit area}} = \frac{5500 \text{ lb}}{36 \text{ sq in.}}$.

From these measurements expressible moisture index (EMI) was calculated by the formula:

$$EMI = \frac{\text{(muscle area, sq cm)}}{\text{(muscle + fat + juice spread, sq cm) - (muscle area, sq cm)}}.$$

Values for pH were determined with a slurry of 5 g of meat and 50 ml distilled water blended at high speed for 2 min in a Waring blender. After the slurry reached room temperature, it was stirred with a magnetic stirrer for 30 sec and pH was measured with a Beckman pH meter. Prior to taking a second reading, the beaker was turned 180°, and the mixture stirred an additional 15 sec.

Duplicate determinations of percent total moisture and percent extractable fat were made for each sample. Approximately 5 g of the ground meat was placed in a weighed Whatman 22 x 80 single thickness extraction shell that had been dried for 16 hr to a constant weight in a vacuum oven (65°C, 27 in.Hg). The samples were dried in a warm oven (65°C) prior to drying for 16 hr in a vacuum oven. Initial samples were dried an additional 2 hr. Since no weight change was noted, it was assumed a constant weight was obtained after drying 16 hr. Dried samples were cooled in a desiccator and weighed. The percentage of moisture was calculated. A Goldfisch apparatus was used for extraction of crude fat. After 4 hr of extraction with petroleum ether the samples were dried in a vacuum oven for 2 hr, cooled in a desiccator and weighed, and the percentage of extractable fat was calculated (AOAC, 1955). Initial samples were extracted an additional 2 hr and no difference in percent fat was found.

Percentage fat-free dry weight was calculated from data obtained during determination of percent moisture and fat. Fat-free dry weight of muscle represents protein and soluble non-protein substances. Approximately 79% of meat is water and fat. Of the remaining portion, 18% is protein (Lawrie, 1966). Therefore, percent fat-free dry weight is a crude approximation of the amount of protein present.

CHAPTER IV

RESULTS AND DISCUSSION

I. TREATMENT EFFECTS ON EXPRESSIBLE MOISTURE INDEX, TOTAL MOISTURE, AND FAT-FREE DRY WEIGHT

The interaction effects of cooking time and added water resulted in significantly different expressible moisture index (EMI) values for all nine treatments (Table III). In the three uncooked samples, EMI decreased as the level of added water increased. A greater decrease in EMI occurred between the 0 and 15 ml water levels than between the 15 and 30 ml water levels. As added water increased from 0 to 30 ml in the raw sample, a 41% decrease in EMI occurred. After heating 70 sec, the change from no added water to 30 ml was 43%, essentially the same as in the raw sample.

TABLE III

TREATMENT EFFECTS ON EXPRESSIBLE MOISTURE INDEX[1]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	0.97	0.69	0.57
70	0.70	0.60	0.40
130	0.26	0.24	0.22

[1]All values are significantly different ($P < 0.01$).

In the 70 sec samples, the percent decrease in EMI values from 0 to 15 ml water was only half as much as the decrease observed for these water levels at the 0 sec cooking time. However, the percent decrease in EMI from 15 to 30 ml in the 70 sec samples was nearly twice as great as the decrease in the raw sample with similar water levels.

For the 130 sec samples, the differences among EMI values were not as great as those noted at the other cooking times. This caused the percent difference between water levels to be similar to the percent of moisture added to each sample. At all water levels expressible moisture index decreased as time of cooking increased.

The percent difference in values for the raw (0 sec) and 70 sec samples was less than that between the samples cooked 70 and 130 sec. Also, there was little visual difference in the pressed meat from the 0 and 70 sec samples. However, the pressed samples that had been cooked 130 sec possessed a similar appearance and generally were thicker and did not spread as much as samples from the two other cooking periods.

The end point temperature of the samples was read at the completion of the cooking period and 5 min after removal from the oven. During this 5 min period, the mean temperature of the 70 sec samples increased approximately 7°C to an effective end point temperature of 43° to 47°C (Table XII, Appendix). Based on the findings of Hamm et al. (1960) some protein denaturation should have occurred at these temperatures resulting in an unfolding of protein chains, disappearance of acidic groups, and a tightening of the protein network causing a decrease in water holding capacity.

Five minutes following cooking, the 130 sec samples achieved an effective end point range of 61° to 64°C (Table XII, Appendix). In a preliminary study, maximum temperatures were attained within a 5 min interval. It was at the higher end point range of 61° to 64°C that the greatest change in EMI occurred. Hamm (1960) reported decreased water holding capacity at 55°C and suggested that the loss in water holding capacity was near completion between 60° and 70°C.

Of the nine variations, the lowest EMI values were for the 130 sec samples. In some cases EMI values for cooked samples (70 sec, 0 ml and 70 sec, 15 ml) were similar to those for uncooked samples (0 sec, 15 ml and 0 sec, 30 ml, respectively) containing greater levels of water. The greatest water holding capacity was in the raw sample with no added moisture (0 sec, 0 ml). Since there was not an appreciable variation in end point temperatures at the three water levels, added water did not seem to increase the rate of microwave cooking for these samples. This might be attributed to the maintenance of a constant water level in the oven.

Percentage total moisture values were significantly different for the nine treatments as a result of the interaction effects of cooking time and added water (Table IV). The percent total moisture retained in the uncooked samples increased as the water level increased. For all cooking times there was a greater percent retention of water between 0 and 15 ml than between 15 and 30 ml.

TABLE IV

TREATMENT EFFECTS ON TOTAL MOISTURE (%)[1]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	74.26	76.15	77.34
70	72.98	74.61[a]	74.76[a]
130	70.56	72.53	73.45

[1]All values are significantly different ($P < 0.001$) except those with a common superscript ($P < 0.05$).

The uncooked samples with 30 and 15 ml added water retained the greatest percentage total moisture and the 70 sec samples containing 30 and 15 ml water ranked just below these. The 0 sec, 0 ml sample and the 70 sec, 15 ml sample had similar moisture retention. The added water seemed to counteract the heating effect of decreased moisture. The sample cooked 70 sec with no added water retained more moisture than the samples cooked 130 sec containing 15 ml added water. The 130 sec, 0 ml sample retained the least percentage of moisture. Values for total moisture for the 0 ml sample tended to agree with values reported by Rogers et al. (1967) for intact pectoralis major muscles heated to end point temperatures similar to those used in this study.

A summary of the variations attributable to treatments and error for EMI and total moisture is presented in Table V. These percentages are based on components of variance calculated from the mean squares used in the analysis of variance. Eighty-five percent of the variation in EMI

was attributed to treatment, whereas 72% of the variation in total moisture was caused by treatment. Part of this increased error might have resulted from freezing the samples between the time of cooking and the determination of total moisture.

TABLE V

SOURCES OF VARIATION (%) FOR EXPRESSIBLE MOISTURE INDEX AND TOTAL MOISTURE

Source	Expressible Moisture Index	Total Moisture
Added water	14.55	22.06
Cooking time	55.69	43.41
Interaction	15.18	6.12
Among birds	0.00	0.00
Between duplicates (error term)	14.55	28.39

The effects of added water, cooking time, and their interaction for both EMI and percent total moisture were evaluated as highly significant by the F ratios calculated in the analysis of variance (Table XIII, Appendix).

The percent fat-free dry weight of the samples (Table VI) was calculated from data obtained during moisture-fat determinations. Differences in percent fat-free dry weight for the different water levels were significant when samples cooked the same length of time were grouped together. Likewise, the effect of cooking time was significant when

samples from the same water level were grouped together (Table XIV, Appendix). However, the F ratio for the analysis of variance (Table XIII, Appendix) indicated the interaction of cooking time and added water was not significant. A trend toward decreased fat-free dry weight was noted as water levels increased at all cooking times (Table VI). Increased heating time tended to increase percent fat-free dry weight.

TABLE VI

TREATMENT EFFECTS ON FAT-FREE DRY WEIGHT (%)[1]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	25.24	23.37	22.78
70	26.45	24.77	24.68
130	28.78	26.96	26.00

[1]Values are not significantly different.

For all samples, percent fat-free dry weight tended to decrease as percent total moisture (Table IV, page 25) increased and EMI (Table III, page 22) decreased. Added water resulted in decreased values for both fat-free dry weight and EMI. Swift et al. (1959) reported water retention was inversely related to protein content in several bovine muscles.

II. TREATMENT EFFECTS ON INITIAL AND TOTAL COOKING LOSSES

Percentage initial cooking loss was calculated from the weight of samples prior to cooking and immediately after cooking. Significant differences in initial cooking losses were attributed to the combined effects of cooking time and added water (Table VII). At both 70 and 130 sec, losses increased as a result of increased water level. The percentage increase of loss from one water level to another was less for the 130 sec than for the 70 sec samples. The percentage increase in percent loss from 0 to 30 ml in the 130 sec samples was less than one-third of the percentage loss found between 0 and 30 ml in the samples cooked 70 sec.

TABLE VII

TREATMENT EFFECTS ON INITIAL COOKING LOSS (%)[1,2]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	--	--	--
70	5.1	7.0	12.3
130	14.5	17.8	20.4

[1]Calculated from weights determined immediately after cooking.

[2]All values are significantly different ($P < 0.001$).

As time of cooking was increased, initial losses increased at all water levels. The percent increase in loss was greater at 0 ml than at 15 ml and greater at 15 ml than at 30 ml.

Total cooking losses were calculated from weights taken 5 min after removal of the samples from the oven. Since end point temperature did increase during this interval, total cooking losses were greater for all variables following 5 min (Table VIII).

TABLE VIII

TREATMENT EFFECTS ON TOTAL COOKING LOSS (%)[1,2]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	0.2	0.7	2.5
70	9.6	12.7	18.4
130	17.5	21.2	24.1

[1]Calculated from weights determined 5 min after cooking.

[2]Values are not significantly different.

There were significant differences in total losses attributable to added water when samples cooked the same length of time were grouped together. Likewise, the effect of cooking time was significant when samples from the same water level were grouped together (Table XIV, Appendix). However, the interaction effects of water and time did not produce significant differences in total cooking losses.

During the cooking of intact muscles, Rogers et al. (1967) reported increased total losses as end point temperature increased. The greatest increase in loss occurred between the 45° and 55°C end points.

In samples with no added water, the values for percentage total loss for this study closely agree with percentage losses reported by Rogers et al. (1967) at 45° and 65°C end point temperatures.

Samples for a given cooking time were similar in appearance. Samples cooked 70 sec with internal temperatures of 43° to 47°C appeared rare in the center of the patty where the bulb of the thermometer was located. However, there was an outer ring approximately 2.5 cm wide that resembled the appearance of the samples cooked 130 sec. The 130 sec samples with internal temperatures of 61° to 64°C appeared uniformly cooked in most cases.

The percentage variations attributable to treatments and errors for initial and total cooking losses are presented in Table IX. Total losses were based on effective end point temperature and in all cases these were greater than initial cooking losses. Cooking time accounted for the greatest percentage variation in both cases but time had less effect on total losses than on initial cooking losses. Added water accounted for approximately 6% of the variation in both cases and there was no measurable variation attributable to among bird differences. For both initial cooking losses and total cooking losses the calculated F ratios for the effects of water and time were significant (Table XV, Appendix). The variation attributed to interaction or combined effects of water and time for initial losses was similar to the variation caused by added water. However, interaction effects on total cooking losses were not found.

TABLE IX

SOURCES OF VARIATION (%) FOR INITIAL AND TOTAL COOKING LOSSES

Source	Initial Cooking Loss	Total Cooking Loss
Added water	6.00	5.61
Cooking time	87.70	66.90
Interaction	6.27	0.97
Among birds	0.00	0.00
Between duplicates (error term)	0.01	26.51

Since total cooking losses were based on effective end point temperature, the percent variation for total losses was more realistic than the values for variation in initial cooking losses. Treatment accounted for 73% of the variation in total cooking losses and 99% of that for initial cooking losses. These data indicate the importance of standardization of time for taking the weights of the cooked samples.

In preliminary work it was determined that maximum end point temperature of the samples would be attained 5 min after heating. During the 5 min required to attain the maximum end point temperature, sample weight decreased to approximately 160 g. Also, it was during this time that variation occurred accounting for differences in the effect of treatment for initial and total cooking losses.

III. TREATMENT EFFECTS ON EXTRACTABLE FAT AND pH

The interaction effects of added water and cooking time resulted in significant differences in percentage extractable fat (Table X). Heating for either 70 or 130 sec resulted in increased values for percentage extractable fat when compared to data for the raw (0 sec) sample. However, the 15 and 30 ml samples cooked 70 sec contained more extractable fat than samples cooked 130 sec. The absolute percentage increase in extractable fat from the raw to the 130 sec cooking time was 0.16% in samples with 0 and 30 ml added water. The increase from the 0 sec, 15 ml to the 130 sec, 15 ml samples was only one-fourth (0.04%) as great.

TABLE X

TREATMENT EFFECTS ON EXTRACTABLE FAT (%)[1,2]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	0.48	0.45	0.38
70	0.56	0.61	0.55
130	0.64	0.49	0.54

[1]All values are significantly different ($P < 0.05$).

[2]Wet weight basis.

Increasing the water level decreased the percentage extractable fat in the 0 and 130 sec samples. The total decrease from the 0 to the 30 ml samples was 0.10% at both cooking times. When compared with the 0

ml samples, the extractable fat of the 70 sec samples increased at the 15 ml water level and then decreased approximately the same amount when water level was increased to 30 ml.

Comparison of data for percentage extractable fat and percentage total moisture (Table IV, page 25) indicated that as total moisture decreased, fat level increased when samples were heated from the raw to either 70 or 130 sec. However, the decrease in moisture observed between the samples heated 70 and 130 sec was accompanied by decreased extractable fat values in samples containing 15 and 30 ml added water. Although significant differences in percentage extractable fat existed among birds (Table XV, Appendix), the mean extractable fat content of the ground pectoral muscles was 0.52% when means from all treatments were grouped together. Based on wet sample weights, Hoke et al. (1968) reported 0.6% ether extractable fat content in cooked samples of poultry pectoralis major muscle.

Significantly different pH values (Table XI) were attributed to the interaction effects of cooking time and added water. When compared with data for the raw sample (0 sec), heating for 70 sec resulted in no consistent change in pH at the three water levels. Heating for 130 sec increased the pH of the samples at all water levels.

Although data for pH values did not vary consistently with cooking time, there was an increase in pH from 5.56 for the 0 sec samples (7° to 9°C) to 5.64 for the 130 sec samples (61° to 64°C). Thus, pH increased approximately 0.08 unit as temperatures of the samples increased from 7° to 9°C to an end point of 61° to 64°C. Rogers et al. (1967) reported

an increase in pH values of 0.11 unit in intact pectoralis major muscles with end point temperatures of 10° and 65°C.

TABLE XI

TREATMENT EFFECTS ON pH[1]

Cooking Time (sec)	Added Water (ml)		
	0	15	30
0	5.56[a]	5.56[a]	5.58[b]
70	5.56[a]	5.58[b]	5.56[a]
130	5.62	5.70	5.60

[1]Values with the same superscript are not significantly different. All other values are significantly different ($P < 0.001$).

CHAPTER V

SUMMARY

The effect of added water and microwave heating on several characteristics of ground composites of pectoral muscles of eight USDA Grade A turkey toms was investigated. Samples (200 g) containing 0, 15, or 30 ml added water were prepared and heated in a Raytheon Mark IV Radarange (2450 MHz) for 0, 70, and 130 sec. Water added in the amounts of 15 or 30 ml represented 7 or 13% of the sample weight prior to heating.

Expressible moisture index and total moisture decreased with increased cooking times, whereas fat-free dry weight and initial and total cooking losses increased with cooking. Extractable fat and pH tended to increase when comparing raw and cooked samples.

Increasing the water levels in the samples resulted in decreased values for expressible moisture index and fat-free dry weight. Total moisture and initial and total cooking losses increased as the level of added water was increased. The effects of added water on extractable fat and pH were not consistent.

Expressible moisture index seemed to be the best measure of treatment effects since a greater percentage variation attributable to treatment was observed for this measurement than for the measurements of cooking losses and total moisture. Although water was lost during cooking, as indicated by total moisture values, it was possible to retain

some added water. Cooking time contributed the greatest percentage variation, but added water also had significant effects on all the characteristics studied. The rate of microwave heating did not seem to be affected by the addition of water. This might be attributed to the maintenance of a constant water load within the oven.

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APPENDIX

TABLE XII

INTERNAL TEMPERATURES[1] OF TURKEY PATTIES

	Added Water (ml)								
	0			15			30		
Cooking Time (sec)	0	70	130	0	70	130	0	70	130
Initial temperature	7.5	8.0	7.2	7.9	8.3	8.0	8.6	8.6	8.0
ICT[2]	7.5	35.4	51.9	7.9	36.1	65.2	8.6	40.0	57.1
TCT[3]	7.8	43.6	61.1	7.9	43.2	62.5	8.9	46.8	63.8

[1]Temperature in °C.

[2]Initial cooking temperatures measured immediately after removal from the oven.

[3]Final cooking temperatures measured 5 min after removal from the oven.

TABLE XIII

F RATIOS FOR EXPRESSIBLE MOISTURE INDEX (EMI), TOTAL MOISTURE (TM), AND FAT-FREE DRY WEIGHT (FFDW)[1]

Sources of Variation	D. F.	EMI	TM	FFDW
Total	143			
Among birds	7	0.99 ns	0.54 ns	0.12 ns
Within bird[2] (error term)	136			
Total treatments	64	67.91 ***	30.40 ***	2.69 ***
Added water	16	49.17 ***	38.30 ***	3.72 ***
Cooking time	16	185.87 ***	74.39 ***	6.26 ***
Interaction	32	18.30 ***	4.45 ***	0.38 ns
Between duplicates[3] (error term)	72			

[1]ns, not significant; ***, $P < 0.001$.

[2]Mean square for EMI, 0.07; for TM, 4.41, for FFDW, 5.66.

[3]Mean square for EMI, 0.002; for TM, 0.30; for FFDW, 3.16.

TABLE XIV

EFFECTS OF COOKING TIME AND OF ADDED WATER ON SELECTED CHARACTERISTICS OF TURKEY PATTIES[1]

	EMI	TM	FFDW	ICL	TCL	Extractable Fat	pH
Cooking Time (sec)							
0	0.74	75.92	23.80	--	1.14	0.44	5.56
70	0.57	74.12	25.80	8.14	13.54	0.57[a]	5.46
130	0.24	72.18	27.25	17.55	20.91	0.56[a]	5.64
Added Water (ml)							
0	0.64	72.60	26.82	6.54	9.09	0.56	5.58[b]
15	0.51	74.43	25.03	8.28	11.52	0.52	5.61
30	0.40	75.18	24.49	10.87	14.97	0.49	5.58[b]

[1]Values with the same superscript are not significantly different. Other values for a characteristic are significantly different ($P < 0.001$) within cooking times and within added water levels.

TABLE XV

F RATIOS FOR INITIAL AND TOTAL COOKING LOSSES (ICL AND TCL), EXTRACTABLE FAT, AND pH[1]

Source of Variation	D. F.	ICL	TCL	Extractable Fat	pH
Total	143				
Among birds	7	0.72 ns	0.76	7.34 ***	20.56 ***
Within bird[2] (error term)	136				
Total treatments	64	87782.86 ***	34.12 ***	2.19 ***	9.61 ***
Added water	16	21455.40 ***	11.16 ***	2.64 ***	16.28 ***
Cooking time	16	316888.73 ***	122.12 ***	2.28 ***	10.72 ***
Interaction	32	6393.73 ***	1.58 ns	1.93 *	5.72 ***
Between duplicates[3] (error term)	72				

[1] ns, not significant; *, P < 0.05; **, P < 0.01; and ***, P < 0.001.

[2] Mean square for ICL, 61.96; for TCL, 83.28; for extractable fat, 0.05; and for pH, 0.002.

[3] Mean square for ICL, 0.002; for TCL, 5.02; for extractable fat, 0.03; and for pH, 0.002.

VITA

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