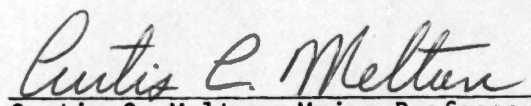


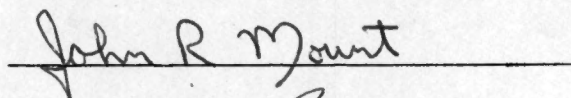
To the Graduate Council:

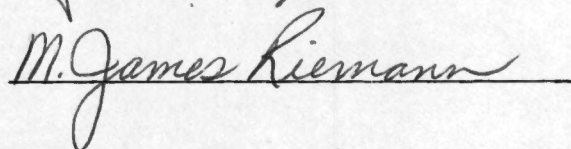
I am submitting herewith a thesis written by Peter Michael Brown entitled "The Influence of Paraffin Wax Coating on Chemical and Sensory Characteristics of Commercially Prepared Country Hams." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.



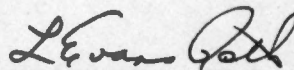
Curtis C. Melton, Major Professor

We have read this thesis
and recommend its acceptance:





Accepted for the Council:



Vice Chancellor
Graduate Studies and Research

THE INFLUENCE OF PARAFFIN WAX COATING ON
CHEMICAL AND SENSORY CHARACTERISTICS OF
COMMERCIALLY PREPARED COUNTRY HAMS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Peter Michael Brown

August 1981

3053762

DEDICATION

This Master's Thesis is dedicated to my parents, Mr. and Mrs. Clarence Brown. Their love, support, and understanding is appreciated more than words can express.

ACKNOWLEDGMENTS

The author wishes to express his utmost appreciation to Dr. Curtis C. Melton whose support, advice, and friendship was the guiding light for this study.

To Dr. J. T. Miles, thanks for your understanding and support.

Special thanks go to Dr. Sam Winfree, the creator of this project, and to Dr. M. J. Riemann and Dr. J. R. Mount for serving as committee members and advisors.

The highest regards go to Alan Benton, Arthur and Benny, at Smokey Mountain Country Hams, who made this study possible because of their support.

The greatest appreciation is expressed to Jody Davis whose laboratory expertise provided the basis for all of the chemical analysis.

The author's praise also goes to Bobby Grindstaff, Andrea Volmi, Kathi Dunn, Sonja Gregory, Adriance Prater, Donna Owens, and Denise Cardin for their cooperation in helping to make this work possible.

ABSTRACT

A total of 48 hams were initially cured in a similar manner country style. Upon completion of equilization, 24 of the hams were randomly chosen and covered with paraffin wax, while the remaining 24 hams were unwaxed. Twenty-four of these hams, 12 waxed and 12 unwaxed, were allowed to age 100 days and the other 24 were aged an additional 200 days. At the end of the aging period, center slices were removed from each ham for chemical and sensory analysis.

The waxed hams shrank 0.28 lbs. after 100 days while the unwaxed hams shrank 1.04 lbs. and after 200 days the waxed hams shrank to 0.69 lbs. while the unwaxed hams shrank 1.97 lbs. This shrinkage was significantly different ($p < .01$). The waxed hams maintained a significantly ($p < .01$) higher percentage moisture level of 54.21% compared to 52.16% for unwaxed at 100 days and 51.24% waxed compared to 46.25% unwaxed at 200 days. Protein levels also differed ($p < .01$) with the unwaxed hams having 26.78% compared to 23.81% for the waxed hams at 100 days and unwaxed 31.31% compared to 26.66% for waxed hams at 200 days. Ph differed ($p < .01$) for all hams between 100 days (5.89) and 200 days (5.67). There were no significant differences found for salt, titratable acidity, fat, or TBA. In the sensory analysis the hams were divided into the semimembranosus, semitendinosus, and vastus group. These groups were analyzed by a trained panel for degree of saltiness, aged flavor intensity and tenderness. Significant differences ($p < .05$) were found for the semitendinosus between waxed and unwaxed hams and time of aging period for degree of saltiness although both were

satisfactory. There were no significant differences found between waxed and unwaxed for aged flavor intensity in any of the muscle groups. Time of aging period was significant ($p < .05$) for all muscle groups. Significant differences ($p < .05$) were found between waxed and unwaxed hams for tenderness in the semimembranosus, with the waxed hams being more tender. Time of aging for tenderness was not significant for any group. Simple correlation coefficients were found significant ($p < .01$) for the semitendinosus degree of saltiness correlated to all but the vastus muscle group for aged flavor intensity.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. REVIEW OF LITERATURE	3
The Action of Salt	3
The Action of Sugar	5
The Action of Nitrite	6
The Effect of Paraffin Wax Coatings on Ham	6
III. EXPERIMENTAL PROCEDURE	9
Fat Determination	11
Moisture Determination	12
Crude Protein Determination	13
pH and Titratable Acidity Determination	14
2-Thiobarbituric Acid Determination	15
Salt Determination	16
Sensory Evaluation	16
Preparation of Samples	17
Statistical Analysis	17
IV. RESULTS AND DISCUSSION	19
Shrinkage During Aging	19
Economic Considerations	19
Chemical Analysis	21
Sensory Analysis	26
Insect Observation	27
BIBLIOGRAPHY	32
APPENDICES	35
Appendix 1	36
Appendix 2	37
VITA	38

LIST OF TABLES

TABLE		PAGE
1.	The Effect of Aging Time and Wax Coating on Shrinkage of Country Hams	20
2.	Means and Standard Deviations for Moisture, Fat and Protein in Waxed and Unwaxed Hams Aged 100 and 200 Days . .	22
3.	Means and Standard Deviations for pH, Titratable Acidity, Salt and TBA in Waxed and Unwaxed Hams Aged 100 and 200 Days	25
4.	Means ¹ of Sensory Attribute for the Semimembranosus (SM), Semitendinosus (ST), and the Vastus Group (VG) of Waxes (W) and Unwaxed (U) Ham Center Slices Aged 100 and 200 Days	28
5.	Combined Means ¹ and Standard Deviations for Sensory Analysis for Degree of Saltiness, Intensity of Aged Flavor, and Tenderness of Waxed and Unwaxed Hams Aged 100 and 200 Days	29
6.	Simple Correlation Coefficients Between Degree of Saltiness and Intensity of Aged Flavor	31

CHAPTER I

INTRODUCTION

The art of curing hams has long been a tradition in many regions of the world. In this nation country cured hams are in great demand because of the distinctive aged flavor as contrasted to the quick cured "packing house hams," Erwin (1968).

The original purpose for curing hams was preservation, that is, the interaction of salt on the meat tissue to retard spoilage. With the universal availability of refrigeration, dry curing of meat for preservation is no longer of such prime importance. Country hams are now considered a speciality item.

Methods of curing are directed at producing a desirable aged flavor and avoiding undesirable external factors favoring the development of putrefactive bacteria according to Edelman et al. (1939). The fact that country hams are exposed to extrinsic factors such as temperature, humidity, and insects for long periods of time suggest that alternative aging methods should be considered.

Melton and Maxedon (1979) demonstrated that country hams can be coated with U.S.D.A. food quality paraffin wax during aging. Paraffin wax has been used extensively in the cheddar cheese industry as an external coating to retard mold growth, increase storage time, and promote aging (Swett, 1953).

Country ham producers are faced with numerous problems during the curing and aging time period. An acceptable country ham should be aged between six months and one year to achieve the desirable aged flavor. Within this period of time shrinkage occurs, temperature and humidity can

vary, and insects can have deleterious effects. All of these factors result in monetary losses to the producer. Therefore, it would be desirable to develop a procedure whereby the aged flavor of country ham is achieved in a shorter period of time.

It was the purpose of this study to determine the effects a paraffin wax coating on the external surface of aging country hams has on reducing shrinkage, altering aging time, improving sensory properties, and providing a barrier against insect invasion. The data will provide information regarding consumer as well as commercial producer acceptability of a waxed coated country ham.

CHAPTER II

REVIEW OF LITERATURE

Most good meat-curing mixtures should contain salt, sugar, and salt peter, according to Helser (1929) and Warner (1938). According to Ziegler and Miller (1938) the amount of curing mixture to apply per pound of fresh ham to produce a mild-flavored cured ham is one to one and one-fourth ounces of an 8:3:3 mixture of salt, sugar, and sodium nitrate respectively per pound of green ham. This should be applied in three rubbings and the hams left in cure a minimum of two days per pound of green ham.

The Action of Salt

Salting is the oldest known form of meat preservation. Salt is also the most common and the most important of all the ingredients used in curing meat products as described by Tomhave (1925). It causes a loss of water from the meat tissue, a necessary reaction in producing a country ham. According to the U.S.D.A., a country cured ham must attain a minimal weight shrinkage of 18% to be considered aged. Salt also plays an important role in retarding the growth of undesirable bacteria which commonly have access to meat. Miller and Ziegler (1936) stated that the main function of salt is as a preservative to prevent or reduce the action of microorganisms which might cause spoilage in the meat, but that it also contributes greatly to the palatability of the meat. Salt should be used to the extent of preventing spoilage, but not in excess quantities that would result in unacceptable palatability.

In country ham curing, salt is rubbed on the external surface of

the ham in usually three successive rubbings every seven to ten days. At this point the salt has only penetrated the surface. A ham producer must allow for this salt to further penetrate the tissue through its own action known as equilization.

Time, as previously stated, and temperature of 40°F are the critical factors during equalization and must be controlled to assure a uniform salt distribution. Upon completion of the rubbing and primary equilization phase the hams are hung on racks and allowed to continue the process of aging at 50°F until the minimal weight loss is achieved.

The shrinkage of the ham occurs as long as the ham is aging, and according to Kemp et al. (1961) the higher the temperature of aging the more the weight loss. Sometimes these country cured hams are not uniform in quality and show as much as 30% weight loss during the aging period, Shelley and Kemp (1963). Kemp et al. (1957) used an aging room at 65°F with a relative humidity of 60% and produced acceptable hams, in six months. Cecil and Woodruff (1954) also produced hams in shorter periods of time with higher temperatures.

Weight and thickness of the hams to be cured are also important factors in the length of time necessary for optimal salt penetration throughout the ham tissue according to Ziegler and Miller (1938). Blumer et al. (1952) found that the rate of salt distribution was affected by the weight of the ham, salt absorbed, and the distribution of fat. There was a significant negative correlation between the salt absorbed per pound of ham and the fatness of ham.

According to Ziegler and Miller (1938) the concentration of salt in the outside of the ham is at minimum, ten times as great as it is in the center at the time they are removed from cure. They also found that

the temperature at which the salt was effective in preventing bacterial action, 36° to 40°F, also allowed for rapid uptake of cure. In other studies it was observed that salt penetrates a skinned ham more rapidly than a ham that has not been trimmed. This demonstrates that the thicker the fat covering, the less permeable a ham will be to salt penetration. It is also known that the major salt transmission takes place from the cushion side of a ham that is opposite the side having the heavier fat covering.

Callow (1947) states the absorption of salt into fatty tissue is simple, whereas penetration into muscle tissue is more complex. Muscle fibers are filled with fluid immediately after exsanguination due to the accumulation of glycogen. This level of glycogen remains high until glycolysis can convert the glycogen to lactic acid. At this time the fluid volume is decreased and allows for the salt to initiate penetration into the muscle tissue. Spoilage of the muscle tissue can also retard the penetration of salt into the muscle tissue according to Beasley and Carroll (1942).

The Action of Sugar

A primary importance of sugar in a curing mixture is to enhance color development. Sugar serves as a primary constituent in the Malliard or browning reaction of meat tissue. According to Lewis (1937) sugar is also known to reduce the hardening effect or harshness due to the abundant amounts of salt present. Some investigators state that the addition of sugar to a curing mixture elicits a more desirable sweet flavor, but Brady et al. (1949) suggests that the final flavor of sugar is masked by the presence of stronger flavors related to age and rancidity. They

also found that sugar has its greatest effect at the beginning of the curing process, but from a long-term standpoint sugar does not have an effect on the chemical or taste attributes of a country ham.

The Action of Nitrite

Nitrite, either as a potassium or sodium salt, is used to develop cured meat color. It is very important to develop an attractive, stable color in cured meat. The basic reaction occurring during color development is as follows:



Nitric oxide myoglobin has an appealing, bright red color, and is the pigment present in cured country ham.

Another important reason for adding nitrite to the curing mixture is to inhibit microbial growth that could result in spoilage. Nitrite is known to inhibit Clostridium botulinum organisms which could readily grow and produce toxin in anaerobic situations.

Nitrite is also used as an antioxidant to prevent too much oxidation of the country ham tissue which could result in unacceptable flavor. This antioxidant quality is often discussed as the ability for nitrate to enhance the flavor of aged country hams.

The Effect of Paraffin Wax Coatings on Ham

Trimming losses, off flavors, and unattractiveness due to mold growth are still problems in the storage of cured meats. Bray and Hanning (1949) investigated the approach of applying a material, such as paraffin wax, to act as a cover on the outside of cured cuts to

inhibit mold growth and retain the natural quality of the meat. They observed that proprietary wax No. 1 offered good protection against mold growth until breaks appeared in the coating. This breaking was due to the use of a wax that was too brittle to remain adhered to the ham surface. On their second approach a material termed proprietary wax No. 2 offered excellent protection and no mold growth was evident on the meat treated in this manner. These researchers explained that the proprietary wax No. 2 had the property of remaining soft and pliable through the storage time and temperature.

The first proprietary wax, although brittle, prevented excess moisture loss, while the second wax reduced moisture losses to a negligible amount. Bray and Hanning (1949) commented that excessive moisture losses in meat might bring about changes in the meat which might affect its quality. They went on to explain the large monetary losses that could occur on the commercial level from excessive loss of moisture.

The use of proprietary wax No. 2 gave a product which their taste panel judges could distinguish from the untreated control and even preferred.

Melton and Ubbaonu (1980) investigated the effect of paraffin wax coating on fatty acids in country hams. They found the wax covering caused no adverse effect on the flavor influencing fatty acids, therefore suggesting the wax covering might serve as an excellent packaging material for long aged dry-cure hams.

Abundant mold growth is often observed on the surface of country cured hams and is associated with sufficient age time according to Ayres et al. (1980). However, some researchers have reported that fungi isolated from country hams are capable of producing mycotoxins. In

addition, many people find the appearance of mold on food distasteful according to Draughon et al. (1980). Dipping cured hams in melted paraffin wax before aging has been suggested as a means to maintain the desired moisture level and reduce surface mold growth. Draughon et al. (1980) investigated surface microflora of country cured hams aged in stockinettes, barrier bags, and paraffin wax. The predominant genera of mold isolated was Penicillium. Aspergillus, Cladosporium, Scopulariopsis, and Epicoccum were also isolated. They found that waxing the hams markedly reduced the surface growth of mold on ham surfaces. Cladosporium and Epicoccum which cause "black spot" on hams were not isolated from waxed hams. Since "black spot" must be cut out of hams resulting in economic loss, their elimination by waxing is a distinct advantage according to Draughon et al. (1980). This more recent finding concerning the reduction of mold growth due to paraffin wax coating is in agreement and substantially backs up the findings of Bray and Hanning (1949).

CHAPTER III

EXPERIMENTAL PROCEDURE

A total of 48 hams varying in weight, fat thickness, and muscle quality were purchased from East Tennessee Packing Company and delivered to Smokey Mountain Country Hams in Madisonville, Tennessee. The initial weight of each ham was recorded.

All the hams were initially processed at the same time by hand rubbing with a curing mixture of NaCl, sugar, and sodium nitrite. The amounts used were 8 lbs. NaCl, 3 lbs. sugar, and 1 oz. sodium nitrite per 100 lbs. of ham respectively. Care was taken to avoid separation of the muscles during rubbing and to assure as even a distribution of curing mixture as possible. The rubbing procedure was repeated twice 14 days apart following the initial rubbing. All hams were then placed in refrigeration at 45°F and allowed to absorb the cure for at least 2 days per pound of ham. This initial absorption time lasted 40 days. Upon completion of the initial salt absorption time period, individual weights were again recorded to check for percent shrinkage. At this time the hams were suspended shank up by stainless steel hooks on wooden racks and allowed to equalize at approximately 50°F, removed from equilization and aged until 18% minimal shrinkage level was reached.

When shrinkage reached 18%, all hams were weighed and randomly selected for the waxing treatment. There were 24 hams that received the wax treatment and 24 hams left untreated with wax to serve as controls. The hams were treated with a U.S.D.A. food grade paraffin wax heated to approximately 180°F. The wax was melted to a liquid state

in a large stainless steel meat lug mounted on a series of three gas burners. Each ham to be waxed was dipped sufficiently to insure total coverage of the ham with wax. The stainless steel hook was left in the shank of the ham during waxing and care was taken when replacing hams on the aging rack to protect against disrupting the wax coating.

The 48 hams were divided into groups 1 and 2, each containing 12 waxed and 12 unwaxed hams (controls). The hams were then placed on aging racks according to their groups numbered Group 1 and Group 2. Group 1 was allowed to age 100 days after wax application and Group 2 was allowed to age 200 days past waxing.

After completing 100 days of aging, Group 1 and Group 2 hams were removed from the racks and weighed. The wax coating was removed from the 12 hams in that group and the weight of the wax was also recorded. Wax removal was accomplished by chilling the hams sufficiently to cause the wax to become brittle allowing for easier scraping of the wax from the hams. Group 1 hams were visually observed for mold growth and insect damage.

There were three center cut slices that included all the muscle groups and measured approximately three-eighths inches in thickness, removed one inch distal from the aitch bone on each ham. These three center slices from each ham were labeled A, B, and C, according to the order in which they were removed. Portion A was used for chemical analysis and portions B and C were used for sensory evaluation. All slices were individually double wrapped and labeled pending analysis and sensory. Upon return to The University of Tennessee Meats Laboratory, portion A was prepared for laboratory analysis by trimming

of excess fat and cutting into one-half inch pieces. These pieces were combined with liquid nitrogen at -196°F for instantaneous freezing. After freezing, the cubes were put into a stainless steel container and powdered using a Waring blender to insure a homogeneous sample for analysis. Each sample for chemical analysis was labeled and packaged in a whirl-pack bag and stored at 0°C . Portions B and C were also stored at 0°C in a double wrapped high quality wax-lined meat paper.

Group 2 hams were cut and sampled after 200 additional aging days. These 24 hams, including 12 waxed and 12 controls, were weighed and prepared for further analysis using the same procedure discussed above for the Group 1 ham samples.

Fat Determination

Hams purchased from a packing company and shipped to a country ham producer may possess great variation in fat thickness. The amount of fat covering on a ham can have a marked effect on ham quality and uniformity of salt penetration during curing. The comparison of sensory results to known fat thickness of individual hams could be beneficial to both meat researchers and commercial country ham producers.

Fat content was determined by the Soxhlet method (AOAC, 1975). Upon completion of the moisture determination, the dried sample was utilized in the fat analysis.

The dried samples in lots of 10 were placed in a Soxhlet reflux tube. Anhydrous ether enters the reflux chamber and continually flushes the samples for at least eight hours. Upon completion of the ether extraction, the samples were removed from the Soxhlet apparatus and

allowed to first air dry overnight and then dry in a vacuum oven for five hours at 100°C. The samples were removed from drying, placed in a desiccator for 30 minutes to cool, and then weighed. Fat content was calculated by difference before and after ether extraction.

Moisture Determination

Moisture level in country hams is important from both a physical and economic standpoint. As stated earlier, a curing ham must lose a minimum 18% of its weight to be considered a country ham. This weight loss is due to moisture reduction as a result of dehydration from salt and aging. Although a ham must lose 18% by weight, any additional weight loss could be considered an economic loss due to the fact that country hams are sold on a per pound basis. From a commercial standpoint any excessive additional weight loss might result in a damaging monetary loss.

Moisture was determined by the oven drying method. For each sample, in duplicate, a Whatman #1 filter paper was folded, placed on a tray, and dried in a vacuum oven for two hours at 100°C. The paper was then removed, placed in a desiccator, and allowed to cool for 30 minutes. After cooling, the filter paper was removed, labeled for each sample, and its weight recorded. Two grams of country ham sample were placed in the respective filter paper and allowed to dry overnight in the vacuum oven for 12 hours at 100°C. Samples were removed, placed in a desiccator, and allowed to cool for 30 minutes. Each sample's weight was then recorded. Calculations for moisture were determined by difference in sample weight before and after drying.

Crude Protein Determination

The Kjeldahl procedure for cured meat samples as outlined by the A.O.A.C. Laboratory Manual (AOAC, 1975) was used in the determination of percent crude protein for the country ham samples.

There are three basic phases involved in the Kjeldahl procedure. The initial step is digestion, in which the country ham sample for experimentation is broken down to prepare the total nitrogen content for further analysis. Step two involves the removal of the total nitrogen by distillation from the other components of digestion. The final step is the titration of the distillate to obtain total nitrogen for calculation.

The Kjeldahl apparatus was set up to handle five samples and one blank all in duplicate for a total of 12 samples.

One gram sample measured to the nearest thousands was added with 1.2 grams of chromium metal to an 800 ml Kjeldahl flask. At this point the flask was sealed and stored for 48 hours. To the flasks 35 ml distilled H_2O was added and allowed to stand for 10 minutes with occasional swirling. To this, 7 ml of HCL was added and allowed to stand for 30 seconds. The flasks were then placed on preheated burners and heated for 3.5 minutes. The flasks were then removed and allowed to cool. To this mixture 22 grams of K_2SO_4 and 1 gram of HgO plus a few granules of aluminum were added to the flasks. There was also 25 ml of concentrated sulfuric acid added to the mixture and the flasks were then replaced on the preheated burners. The flasks were heated until dense white smoke appeared and then dissipated from the bulb of the flasks. The flasks were swirled and the heated digestion continued for an additional 60 minutes.

For distillation, the flasks were allowed to cool, 300 ml of distilled water was added to bring the temperature below 25°C. The flasks were then tilted and 75 ml of 50% NaOH and 25 ml of thiosulfate along with a few zinc granules were added to initiate distillation. The flasks were placed on the distillation burners and allowed to distill until 200 ml were collected in 500 ml erlenmeyer flasks containing 50 ml 0.1N dilute HCL and six drops of methyl red indicator.

The distillate was titrated with 0.1N NaOH which was calibrated in ml via buret. The 0.1 NaOH was added until the distillate changed from pink to a golden brown. Beginning and ending ml of the NaOH were recorded along with the weights of each sample. A 6.25% conversion factor was used to determine the percent protein in each sample.

pH and Titratable Acidity Determination

For the determination of pH 5.0 grams of homogeneous ham sample were used per ham. The 5.0 gram sample was weighed to the nearest hundredths. The sample was combined with 50 ml of distilled water in a stainless steel container and homogenized for 2 minutes using a Virtis homogenizer. The resultant slurry was then poured into a 100 ml beaker and covered with parafilm until it could be measured for pH.

A Fisher pH meter was used for determining the pH of the country ham samples. The instrument was calibrated at room temperature, 22°C, using buffered solutions with known pH's of 7.0 and 9.0.

The pH of the sample was measured and recorded. A 0.1N NaOH solution was used to bring the pH up to 8.3. The volume of NaOH used was multiplied by the normality of the NaOH to determine the titratable acidity of the sample.

The equation for determining milliequivalents of acid is as follows:

$$\text{meq each sample} = \frac{(\text{ml NaOH}) (\text{N NaOH})}{\text{g}}$$

2-Thiobarbituric Acid Determination

The aged flavor of a country ham is related partially to a mild form of oxidative rancidity. This flavor is desirable in country hams and develops during an extended aging period.

The oxidation of animal tissues and certain lipids produces compounds which will condense with 2-thiobarbituric acid (TBA) to give an orange-red color according to Turner et al. (1953). These compounds include glyoxal, chloral hydrate, malonic dialdehyde, and carbonyl groups.

For rancidity analysis in country hams, TBA reagent 0.02M 2-thiobarbituric acid (F.W. 144.15) in 90% glacial acetic acid was brought into solution by warming slightly in a boiling water bath. Ten grams of homogeneous ham sample was blended with 50 ml of distilled water in a Waring blender for two minutes. The mixture was transferred into a Kjeldahl flask by washing with an additional 47.5 ml of distilled water. Three ml of 4N HCl was added to bring the pH to 1.5. A small amount of Dow antifoam was added onto the lower neck of the flask and a few glass beads added to prevent bumping.

Flasks were heated at the highest heat obtainable on the Kjeldahl distillation apparatus. Fifty ml of distillate was collected taking approximately 10 minutes from the initiation of boiling. The distillate was mixed and 5 ml pipetted into a 50 ml glass stoppered tube and

5 ml of TBA reagent added. The contents in the tubes were mixed and immersed in a boiling water bath for 35 minutes. A distilled water TBA reagent blank was prepared and treated like the samples after heating. After boiling, the tubes were cooled in tap water for 10 minutes. A portion was transferred to a cuvette and the optical density of the sample was read against the blank at a wavelength of 532 mu. A Beckman DU spectrophotometer was used in the analysis. The readings were multiplied by the factor 7.8 to convert to milligrams of malonaldehyde per 1000 gram meat.

A standard curve was prepared by making dilutions of the 1×10^{-3} M TEP malonaldehyde standard solution to give amounts ranging from 1×10^{-8} to 7×10^{-8} moles of malonaldehyde in 5 ml.

Salt Determination

Ten grams of ham sample were added to 90 ml boiling water. This mixture was stirred two times at one minute intervals. Filter paper was quartered and placed over a 150 ml beaker and the extraction poured through filter paper. A quantab testing strip was placed into the liquid collected in the filter paper. A reading was taken after 30 minutes and this value was converted to percentage salt on the batch table provided with the testing kit.

Sensory Evaluation

Panel Training

A total of eight members were selected and trained to evaluate the sensory characteristics degree of saltiness, intensity of aged flavor,

and tenderness. These variables were categorized into a descriptive scale. Refer to Appendix 1 for example of scale.

During training and actual evaluation, three groups of two panelists analyzed the same muscle group. These muscle groups consisted of the semimembranosus, semitendinosus, and the vastus group. Due to the variation between these three muscles, a total for each ham sample was analyzed by totaling and averaging the individual muscle scores.

Preparation of Samples

Each ham sample was coded and prepared for cooking by removing excess fat. The ham slices were broiled at 400°F for 10 minutes in a shallow cookie sheet. For sensory samples the cooked slices were divided into muscle groups and cut into one-half inch by one-half inch squares. These squares were further trimmed to remove any excess fat. The samples were served hot.

Statistical Analysis

Chemical analysis data were analyzed by analysis of variance by comparing sample mean values for unwaxed vs. waxed and 100 day aging vs. 200 day aging.

Sensory evaluation data were analyzed by analysis of variance to determine significant differences in degree of saltiness, intensity of aged flavor and tenderness between waxed and unwaxed hams aged 100 days and 200 days. Refer to Appendix 2 for ANOVA model.

Correlation coefficients were also computed to determine the relationship between sensory variables.

CHAPTER IV

RESULTS AND DISCUSSION

The 48 hams used in this study were initially cured and prepared for aging using the same method. The observations and measurements were made during aging period (100 or 200 days) in which 12 of the hams received the paraffin wax treatment and 12 hams were aged in the normal unprotected condition for each aging period.

Shrinkage During Aging

Prior to waxing, all hams were allowed to shrink to approximately 18% which is the required shrinkage according to U.S.D.A. standards for country hams. The actual shrinkage values ranged from 16.95% to 25.75% with a mean shrinkage of 21.63%.

Upon completion of the additional aging period, significant differences ($p < .01$) in shrinkage were found between the unwaxed and waxed hams at both 100 days and 200 days aging time. The unwaxed hams shrank 1.04 lbs. during the first 100 days aging while the waxed hams shrank only 0.28 lbs. After 200 days aging, the unwaxed and waxed hams had shrunk 1.97 and 0.69 lbs. respectively. Values for shrinkage are listed in Table 1.

Economic Considerations

This study was conducted at a commercial ham curing facility, Smokey Mountain Country Hams, in Madisonville, Tennessee. Utilizing the shrinkage values in Table 1, a theoretical model can be created to

TABLE 1. The Effect of Aging Time and Wax Coating on Shrinkage^a of Country Hams.

Aging Time (days)	Unwaxed	Waxed
100	1.04 ^b	0.28 ^c
200	1.97 ^b	0.69 ^c

^aShrinkage is pounds of weight loss following salt equilizations and during the aging period.

^{b,c}Means in the same row with different superscripts differ ($P < .01$).

assess economic differences between unwaxed and waxed hams. When considering the mean shrinkage values at 200 days aging 1.97 and 0.69 lbs. for unwaxed and waxed hams respectively, there is a difference of 1.28 lbs. per ham. If a producer waxed 1,000 hams per year, and the selling price was \$2.00/lb., then the equation $1,000 \text{ hams} \times 1.28 \text{ lb./ham} \times \$2.00/\text{lb.}$ would result in a gross savings of \$2,560 due to wax coating.

Chemical Analysis

Moisture

Moisture is one of the most important factors related to country ham palatability according to Melton and Winfree (1977). Moisture has been shown to be related to both tenderness and juiciness of meat products according to Forrest *et al.* (1975).

There was a highly significant difference found between unwaxed and waxed hams for moisture level with the waxed hams maintaining a higher percentage of moisture in both the 100 days and 200 days aging periods. Moisture values are presented in Table 2.

The percentage of moisture decreased as aging time increased in both treatments, although the waxed hams maintained a greater margin of moisture retention as aging progressed. The total percentage of moisture loss was twice as great for the unwaxed hams as compared to the hams receiving the paraffin wax treatment.

Fat

Fat is an important factor in country hams because of its contribution to flavor and its ability to serve as an insulator against moisture loss. At the same time, fat has a negative effect on salt penetration according to Tomhave (1925).

TABLE 2. Means and Standard Deviations for Moisture, Fat and Protein in Waxed and Unwaxed Hams Aged 100 and 200 Days.

Variable	Aging Time (Days)			
	100		200	
	Unwaxed	Waxed	Unwaxed	Waxed
Moisture (%)	52.16 $\pm$ 2.19 ^b	54.21 $\pm$ 5.58 ^c	46.25 $\pm$ 3.00 ^d	51.24 $\pm$ 2.01 ^e
Fat (%)	13.78 $\pm$ 2.62	14.26 $\pm$ 3.82	13.96 $\pm$ 2.68	14.29 $\pm$ 2.90
Protein (%)	26.78 $\pm$ 1.86 ^b	23.81 $\pm$ 1.76 ^c	31.31 $\pm$ 2.35 ^d	26.66 $\pm$ 2.15 ^e

^{b,c}Mean in the same row, for 100 days aging with different superscripts differ ($P < 0.01$).

^{d,e}Mean in the same row, for 200 day aging, with different superscripts differ ($P < 0.01$).

In this study, the leaner country hams had the greatest percentage of shrinkage.

No correlation was found between the amount of fat cover and the percentage of internal fat in the ham samples analyzed.

There were no significant differences of percentage fat in waxed vs. unwaxed hams at either 100 days or 200 days (Table 2).

A slightly higher percentage of fat in the waxed hams can be seen in Table 2, but these differences were not significant.

Protein

Meat has always been considered a major protein source in balanced diets. It is within the building blocks of proteins, the amino acids, that we receive the essential amino acids that our bodies need but cannot synthesize.

Listed in Table 2 are the protein percentage values found in this study. Unwaxed hams had 2.97% and 4.65% more ($p < .01$) protein than waxed hams after 100 and 200 days aging, respectively. Unwaxed hams aged 200 days had 4.53% more ($p < .01$) protein than waxed hams aged 100 days. However, the waxed hams aged 200 days had only 2.85% more ($p < .01$) protein than the waxed hams aged 100 days.

pH

The pH of meat is an important factor when considering the water holding capacity of the muscle tissue. According to Forrest et al.

(1975), the optimum pH range for conversion of muscle to meat is 5.3 to 6.0. The higher the pH value, the greater the tendency for the skeletal muscle tissue to retain water in the bound stage (Forrest et al. (1975). The aging of country hams causes the muscle tissue to become dry and promotes enzymatic breakdown of tissues which has been shown to cause a rise in pH values in meat. Values for pH found in this study are listed in Table 3.

There were no significant differences between waxed and unwaxed ham samples. The time of aging did result in highly significant differences for pH values. The longer the hams were allowed to age, 200 days vs. 100 days, the higher the pH values. This may have been due to the increased protein degradation that is related to more advanced aging.

Titratable Acidity

Titratable acidity is an indicator of the acidity in the ham samples. Values for the hams included in this study are listed in Table 3.

There were no significant differences between unwaxed and waxed hams. Also, there were no significant differences between hams aged 100 days and 200 days.

Salt

In country ham production, salt should be considered as the most important ingredient according to Melton and Winfree (1977). The correct amount of salt applied during the salting stage is critical in

TABLE 3. Means and Standard Deviations for pH, Titratable Acidity, Salt and TBA in Waxed and Unwaxed Hams Aged 100 and 200 Days.

Variable	Aging Time (Days)			
	100		200	
	Unwaxed	Waxed	Unwaxed	Waxed
pH	5.73 $\pm$ 0.25 ^b	5.62 $\pm$ 0.15 ^b	5.94 $\pm$ 0.20 ^c	5.84 $\pm$ 0.13 ^c
Titratable Acidity (MEQ)	0.29 $\pm$ 0.05	0.31 $\pm$ 0.05	0.28 $\pm$ 0.08	0.21 $\pm$ 0.07
Salt (%)	9.26 $\pm$ 2.05	7.90 $\pm$ 2.20	8.66 $\pm$ 1.58	8.46 $\pm$ 1.40
TBA (MEQ)	0.010 $\pm$ 0.003	0.008 $\pm$ 0.006	0.007 $\pm$ 0.003	0.009 $\pm$ 0.003

^aAnalyses done according to AOHC, 1978.

^{b,c}Mean in the same row, for 100 days and 200 days aging with different superscripts differ ($P < 0.01$).

obtaining preservation and aged ham flavor. Too much salt will impair the aged flavor of a country ham and result in undesirable flavoring, according to Tomhave (1925). Too little salt will result in spoilage from improper curing and the ham will be unfit for consumption. Values for salt analysis in this study are listed in Table 3. The values found fell within the range of 7.0 to 11.0 percent, which is considered desirable in aged country ham production according to Melton and Maxedon (1979).

The unwaxed hams were slightly higher in salt content, but no significant differences were found between the groups analyzed.

TBA

The desirable aged flavor of country hams is partially the result of rancidity development. In most cases, rancidity is a factor that is associated with the onset of spoilage in meat products, however in country ham production a degree of rancidity is desirable. The hams in this study were analyzed for rancidity and the results are listed in milliequivalents/gram in Table 3.

There were no differences found due to waxing effort or aging time.

Sensory Analysis

Sensory evaluation was performed for each of three muscle groups in the ham center slice, the semimembranosus, semitendinosus, and the vastus groups to determine the effect of waxing on degree of saltiness, aged flavor intensity and tenderness.

Degree of Saltiness

There was no significant difference found between unwaxed and waxed hams or between aging times for degree of saltiness for the semimembranosus.

In analyzing the semitendinosus, significant differences were found between unwaxed and waxed hams with the waxed hams having a more satisfactory salty flavor. Also, significant differences resulted due to time of aging period (Table 4). The waxed hams, due to greater moisture retention at 200 days, possessed a more satisfactory level of salt to the panelists.

There were no significant differences found between unwaxed and waxed hams or time of aging for saltiness in the vastus group. Also there were no significant differences for waxed and unwaxed or time of aging for the combined muscle group analysis. Values for degree of saltiness for the combined muscle groups are listed in Table 5.

Intensity Aged Flavor

Aged flavor is the most critical factor in producing a desirable country ham according to Winfree and Ramsey (1968).

There were no significant differences found between waxed and unwaxed hams in aged flavor intensity for individual or combined muscle groups (Table 4 and 5).

Significant differences ($p < .05$) were found between the 100 day and 200 day hams for aged flavor intensity. The older hams had a more intense aged flavor in all three of the muscle groups analyzed (Table 4).

TABLE 4. Means¹ of Sensory Attribute for the Semimembranosus (SM), Semitendinosus (ST), and the Vastus Group (VG) of Waxes (W) and Unwaxed (U) Ham Center Slices Aged 100 and 200 Days.

Attributes	Aging Time (days)											
	100						200					
	U	W	U	W	U	W	U	W	U	W	U	W
	SM	SM	ST	ST	VG	VG	SM	SM	ST	ST	VG	VG
Degree of Saltiness ^a	3.08	2.96	<u>3.20</u>	<u>2.63</u>	3.11	2.92	2.82	2.92	<u>3.54</u>	<u>3.29</u>	3.04	3.00
Aged Flavor Intensity ^a	5.19	5.01	5.75	5.33	5.51	6.00	5.47	5.72	5.96	5.88	5.33	5.80
Tenderness ^a	<u>4.36</u>	<u>4.86</u>	4.42	5.25	<u>3.87</u>	<u>4.25</u>	<u>4.36</u>	<u>5.11</u>	4.83	4.79	<u>4.13</u>	<u>4.97</u>

¹Means underlined are different ($P < 0.05$).

^aExplanation of numerical values for sensory means are listed in Appendix 2.

TABLE 5. Combined Means¹ and Standard Deviations for Sensory Analysis for Degree of Saltiness, Intensity of Aged Flavor, and Tenderness of Waxed and Unwaxed Hams Aged 100 and 200 Days.

Variable	Aging Time (Days)			
	100		200	
	Unwaxed	Waxed	Unwaxed	Waxed
Degree of Saltiness	3.13 ± 0.49	2.83 ± 0.26	3.07 ± 0.32	3.07 ± 0.23
Intensity of Aged Flavor	5.48 ± 0.44 ^a	5.39 ± 0.42 ^a	5.57 ± 0.48 ^b	5.80 ± 0.26 ^b
Tenderness	4.21 ± 0.79 ^c	4.79 ± 0.77 ^d	4.44 ± 0.93 ^c	4.95 ± 0.44 ^d

^{a,b} Mean in the same row for 100 days and 200 days aging with different superscripts differ ($P < 0.05$).

^{c,d} Mean in the same row, for 100 days and 200 days aging with different superscripts differ ($P < 0.01$).

¹ Explanation of numerical values for sensory means are listed in Appendix 2.

Tenderness

According to Melton and Maxedon (1979), tenderness is difficult to assess in country hams because of their dry, coarse texture.

The waxed hams were more tender ($p < .05$) for the combined three muscle groups (Table 4). Time of aging period was not significant in any group.

Simple correlation coefficients for degree of saltiness, aged flavor intensity, and tenderness for the three muscle groups and combined sensory scores are presented in Table 6. There was a significant difference relationship ($p < .01$) observed between the degree of saltiness in the semitendinosus and aged flavor scores for the semimembranosus, semitendinosus and combined muscle groups (Table 6). Also, significant correlation coefficients were found between combined scores for degree of saltiness and aged flavor intensity (Table 6).

Insect Observation

Visual observations were made on all hams for insect damage. Ham mites can be a problem to country ham producers, especially on older hams. Ham mites attack the surface as well as feeding in cracks and other avenues of entry into the ham. This damage is normally on the butt face and ham face near the aitch bone.

The unwaxed hams in this study that were additionally aged for 200 days showed moderate to great damage. This type of damage resulted in considerable loss due to trimming the damaged portion. The waxed hams aged 200 days showed no mite damage and required no trimming.

TABLE 6. Simple Correlation Coefficients Between Degree of Saltiness and Intensity of Aged Flavor.

Aged Flavor	Degree of Saltiness			
	SM	ST	VG	C
Semimembranosus (SM)	0.27	0.36**	-0.18	0.29*
Semitendinosus (ST)	-0.15	0.47**	0.20	0.37**
Vastus Group (VG)	0.07	0.05	0.05	0.08
Combined (C)	0.17	0.41**	0.07	0.38**

* $P < 0.05$.

** $P < 0.01$.

BIBLIOGRAPHY

BIBLIOGRAPHY

- A.O.A.C., 1975. "Official Methods of Analysis," 12th Ed. Association of Official Analytical Chemists, Washington, D. C.
- Ayres, J. C., J. O. Mundt, and W. E. Sandine. 1980. Microbiology of Foods. W. H. Freeman and Co., San Francisco.
- Beasley, A. K. and F. Carrol. 1942. An improved method for determining the distribution of salt and water in cured hams. J. of Agri. Res. 64: 293.
- Blumer, T. N., F. H. Smith, H. S. Lucas, and W. E. Tyler. 1952. The influence of age of hogs on the ham curing process. J. Anim. Sci. 11: 749.
- Brady, D. E., F. H. Smith, T. W. Tucker, and T. N. Blumer. 1949. Characteristics of country-style hams as related to sugar content of curing mixture. Food Res. 14: 303.
- Bray, R. W. and F. Hanning. 1949. Mold control in stored cured pork. J. Anim. Sci. 8:495.
- Callow, E. H. 1947. The action of salts and other substances used in the curing of bacon and ham. British J. Nutr. 1: 269.
- Cecil, S. R. and J. G. Woodruff. 1954. Effect of storage temperatures on the aging of country style hams. Food Tech. 8: 216.
- Draughon, F. A., C. C. Melton, and D. Maxedon. 1981. Microbial profiles of country-cured hams aged in stockinettes, barrier bags, and paraffin wax. Applied and Environmental Microbiology, p. 1078-1080.
- Edelmann, R., J. F. Mohler, and Adolph Eichorn. 1939. "Meat Hygiene" (7th Ed.). Lea and Febiger, Philadelphia, Penn.
- Erwin, R. S. 1968. Ultraviolet radiation effects on aging hams in high moisture conditions. Thesis, The University of Tennessee.
- Forrest, J. C., E. D. Aberle, H. B. Hedrick, M. D. Judge, and R. A. Merkel. 1975. Principles of Meat Science. W. H. Freeman and Company, San Francisco.
- Helser, M. D. 1929. "Farm Meats." MacMillan Publ. Co., New York, New York.
- Kemp, J. D., H. C. McCampbell, and R. B. Grainger. 1957. Procedure for sampling and laboratory rendering of ham fat and characteristics of hams and fat during aging. Food Tech. 11: 321.

- Kemp, J. D., William G. Moody, and James Goodlett, 1961. The effects of smoking and smoking temperatures on the shrinkage, rancidity development, keeping quality, and palatability of dry cured hams. *Food Tech.* 15: 267.
- Lewis, W. L. 1937. The role of sugar in curing meat. *Proceedings Operating and Chemical Sect., Institute American meat packers.*
- Melton, C. C. and D. Maxedon. 1979. Personal Communication. University of Tennessee, Knoxville.
- Melton, C. C. and C. Ubbaonu. 1980. Personal Communication. The University of Tennessee, Knoxville.
- Melton, C. C. and S. K. Winfree. 1977. Factors affecting country ham palatability. *Tennessee Farm and Home Science Progress Report* 101.
- Miller, R. C. and P. T. Ziegler. 1936. How aging affects the distribution of salt in cured hams. *Food Industry.* 8: 121.
- Miller, R. C. and P. T. Ziegler. 1939. Salt content of cured hams. *Food Res.* 4: 55.
- Shelley, G. C. and J. D. Kemp. 1963. Quick aging of hams. *J. Anim. Science.* 23: 633-637.
- Swett, C. 1953. Cheddar cheese demands a proper finish. *J. Butter, Cheese and Milk Product.* 44: 26.
- Tarladgis, B. G., A. M. Pearson, and L. R. Dugan. 1964. Chemistry of the 2-Thiobarbituric acid test for determination of oxidative rancidity in foods. *J. Sci. Fd. Agric.* 15, 602.
- Tomhave, W. H. 1925. "Meats and Meat Products." J. B. Lippincott Company, Philadelphia, Penn.
- Warner, K. F. 1938. *Pork on the Farm: Killing, Curing, and Canning.* U.S.D.A. Farmers Bul. 1186.
- Winfree, S. K. and C. B. Ramsey. 1968. Effects of ultraviolet light on country hams during aging. *Tennessee Farm and Home Science. Progress Report* 65.
- Ziegler, P. T. and R. C. Miller. 1938. Rate of salt absorption in curing pork. *Penn. Agri. Exp. Sta. Bul.* 355.

APPENDICES

APPENDIX 1

Score Sheet Country Ham Sensory Panel

Date _____ Name _____ Sex _____

	CODE	CODE	CODE	CODE	CODE	CODE
<u>Saltiness</u>						
Too Salty	_____	_____	_____	_____	_____	_____
Slightly Too Salty	_____	_____	_____	_____	_____	_____
Very Satisfactory	_____	_____	_____	_____	_____	_____
Slightly Lacking Salt	_____	_____	_____	_____	_____	_____
Lacks Salt	_____	_____	_____	_____	_____	_____
<u>Flavor</u>						
Extremely Intense	_____	_____	_____	_____	_____	_____
Very Intense	_____	_____	_____	_____	_____	_____
Moderately Intense	_____	_____	_____	_____	_____	_____
Slightly Intense	_____	_____	_____	_____	_____	_____
Slightly Bland	_____	_____	_____	_____	_____	_____
Moderately Bland	_____	_____	_____	_____	_____	_____
Very Bland	_____	_____	_____	_____	_____	_____
Extremely Bland	_____	_____	_____	_____	_____	_____
<u>Tenderness</u>						
Extremely Tender	_____	_____	_____	_____	_____	_____
Very Tender	_____	_____	_____	_____	_____	_____
Moderately Tender	_____	_____	_____	_____	_____	_____
Slightly Tender	_____	_____	_____	_____	_____	_____
Slightly Tough	_____	_____	_____	_____	_____	_____
Moderately Tough	_____	_____	_____	_____	_____	_____
Very Tough	_____	_____	_____	_____	_____	_____
Extremely Tough	_____	_____	_____	_____	_____	_____

- Tenderness
- 8 Extremely Tender
 - 7 Very Tender
 - 6 Moderately Tender
 - 5 Slightly Tender
 - 4 Slightly Tough
 - 3 Moderately Tough
 - 2 Very Tough
 - 1 Extremely Tough

- Flavor Intensity
- 8 Extremely Intense
 - 7 Very Intense
 - 6 Moderately Intense
 - 5 Slightly Intense
 - 4 Slightly Bland
 - 3 Moderately Bland
 - 2 Very Bland
 - 1 Extremely Bland

- Saltiness
- 5 Too Salty
 - 4 Slightly Too Salty
 - 3 Very Satisfactory
 - 2 Slightly Lacking Salt
 - 1 Lacks Salt

Comment Flavor:

Overall Satisfaction:

APPENDIX 2

ANALYSIS OF VARIANCE

Source	DF	SS	MS	F Value
Model	3			
Error	44			
Corrected Total	47			

Source	DF	SS	MS	F Value
Wax	1			
Days	1			
Wax Days	1			

VITA

Peter Michael Brown was born on December 27, 1954 in Oak Ridge, Tennessee. He attended Oak Ridge city schools, graduating from high school in 1972. After attending The University of Tennessee, Knoxville, for one year he attended John Gupton College of Mortuary Sciences, receiving the Associate of Arts degree in 1974. After practicing funeral service, he returned to The University of Tennessee, Knoxville in 1977 where he received the Bachelor of Science degree in Animal Science in March 1979. In August 1981 he received the Master of Science degree in Food Technology and Science.