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I am submitting herewith a dissertation written by Collins Nkeoma Ubbaonu entitled "Development and Acceptability of Cured and Dried Beef Prepared at Ambient Temperatures in a NaCl and Papaya Brine." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Food Technology and Science.-

Curtis C. Melton
C. C. Melton, Major Professor

We have read this dissertation
and recommend its acceptance:

Sharon L. Melton

Shirley D. Jaynes

Wm. R. Backus

Will T. Brett Jr.

Accepted for the Council:

L. Evans Roth
Vice Chancellor
Graduate Studies and Research

DEVELOPMENT AND ACCEPTABILITY OF CURED AND DRIED
BEEF PREPARED AT AMBIENT TEMPERATURES
IN A NaCl AND PAPAYA BRINE

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville



Collins Nkeoma Ubbaonu

March 1982

3058695

DEDICATION

This work is dedicated to the entire family of Mazi Ubbaonu Abba Duru.

"Papa, you started the ball rolling in the right direction when you decided to provide your children with formal education despite the temptation of turning them loose on the farm."

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to Dr. Curtis C. Melton (major professor) and Dr. Sharon L. Melton for their immense help and guidance throughout his graduate studies. It is a big privilege working with them as a team.

The author is very grateful to Dr. H.O. Jaynes, Dr. W.R. Backus and Dr. W.T. Butts for their advice and services as members of his committee. His gratitude is extended to Dr. F.A. Draughon, and Ms. O.G. Sanders for all their help during this study.

To Dr. J.T. Miles and Dr. J.L. Collins, the author wishes to express his sincere thanks for all their help and advice in and out of the classroom throughout his graduate studies.

Special thanks are extended to Ruth Hill, Andrea Volmi, James Ragan, John Brothers, Alan Rich and Donna Owens for their immense, sincere help at several stages in this study.

Special thanks are also due to Roseline Nweze for her help in the formulation and preparation of the traditional Nigerian soup used for the sensory evaluation. The author thanks all the members of the consumer taste panel who have voluntarily given up some time to see him through the last stage of this study.

The author wishes to express his gratitude to Ann L. Lacava of the Manuscript Shop and Lisa Rich for their friendly help in getting this dissertation ready at his affordable time and price.

Many students and staff were very cooperative during this study and the author wants them to know that he appreciates their role in making his graduate work less painful.

The author's academic success would not have been possible without the encouragement and kindness of some special families and friends whose support helped him to suppress the feeling of "home-sick" throughout his seven and half years of studies in the United States. These special people are, Louise, Burt, Sam and Jon Bogart, Justine and Dr. Charles Harris, Chucks and Ernestine Ujah, Pat and Andy Balmer and Grace Butgereit.

The author wishes to conclude this acknowledgement with his sincere appreciation to his alma maters, Berea College, Berea, Kentucky, and The University of Tennessee for providing him with the education which he dearly needed. He is very grateful to his beloved senior brother, Canice Onukaegbe Ubbaonu for providing him with the needed financial support from high school through college.

ABSTRACT

Standard meat curing procedures demand refrigerated systems in addition to salt, sugar and sodium nitrite (Kramlich et al., 1973). These are not readily available in most underdeveloped countries. Meat preservation as practiced in underdeveloped countries is mainly by drying. Such products are either very hard and unacceptable for most average income consumers, or they are susceptible to mold and have a short shelf life. Papaya is easily available in most of the tropical countries and contains proteolytic enzymes used in tenderizing meat (Hay et al., 1953). This study was aimed at producing a more palatable dried meat product having good shelf life with raw materials and equipment likely available in underdeveloped countries.

In each of two replications, beef cubes from Commercial grade beef carcasses were randomly allotted to 36 treatment groups consisting of varying levels of NaCl (0% to 10% in 2% increments) and papaya pulp (0% to 25% in 5% increments) in a curing brine held at 23.9°C for 48 hours. After curing, these cuts were washed and dried for 45 hours at 48.9°C to a water activity of about 0.50 and then stored at 23.9°C in polyethylene bags for two months. After one month and at the end of two months storage, products were observed for surface mold and analyzed for volatile fatty acids, titratable acidity, pH and thiobarbituric acid as indicators of quality loss as the result of both processing and storage effects. Product microbial safety was determined by Castro-Espinoza (1982).

The amount of acetic, propionic and butyric acids in the products decreased with increased salt level in the curing solution. The salt

added slowed rancidity development such that only about 2% salt was needed to keep the TBA number (rancidity indicator) below 0.50. The moisture content of the product increased ($p < 0.01$) with increased salt levels. The added papaya lowered the pH of the initial curing solution (from 7.1 in 0% to 5.1 in 25% papaya) and the pH of the finished product. Papaya also decreased ($p < 0.001$) the amount of propionic acid observed in the product such that only about 5% papaya was needed to lower the value from 7.4 to 3.0 mg/100 g sample. Titratable acidity decreased with increased level of salt but increased ($p < 0.001$) with increased level of papaya. Thus the observed value of titratable acidity depends on the interaction of the salt and papaya effects. Samples stored for two months had higher titratable acidity and lower moisture content than those stored for one month. The amount of acetic and butyric acids observed decreased ($p < 0.001$) with increased storage periods. Products treated with 10% salt and 10% papaya brine were chosen for consumer evaluation because it produced no putrid odors during curing, showed no surface mold during storage, had a relative low amount of volatile fatty acids and low TBA number, and it was found to have acceptable microflora.



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CHAPTER I

INTRODUCTION

In most of the developing countries such as Nigeria, up to 40% of the population are living on diets which are nutritionally deficient. Red meats, if available in the diets, could help to ameliorate the situation since meats are high in protein, B-vitamins, especially riboflavin, thiamin, vitamin B₁₂, vitamin A, iron and zinc (Bender, 1975). But fresh meat has the disadvantage of being bulky and perishable during long distance shipment under normal conditions. Since the refrigeration of food is only a practice of the upper class in Nigeria, cattle are slaughtered and meat is sold in open space markets on the day of slaughter. This practice is satisfactory in the cities since there are always enough consumers to purchase all or nearly all available meat. In the rural communities, the problem is either that red meat is not available because the butchers do not want to risk a large left-over where there is no refrigeration system, or that about 50% of the fresh meat cuts are bought by villagers while the other half is spoiled by microbes. The major, if not the only means of preservation of meat, poultry or fish is heat-smoke drying or combined heat-smoke and sun drying. Heat dehydration of animal tissue is a practice older than history. The process is generally practiced in Nigerian homes and the products, as one might assume, are acceptable to a population which has no choice or cannot afford another choice of foods. The products are accepted not because they are of excellent quality, aesthetically or safety-wise but because a hungry person may prefer to eat today and become sick tomorrow rather than starve.

The problems with dehydrated meat products as produced today in most Nigerian homes range from microbial spoilage, and storage loss as the result of weevils and other insects during storage and transportation in burlap bags, to the difficulty of rehydrating excessively dried products. The microbial spoilage has its origin in the handling of meat in the slaughter house and continues through the unsanitary butcher's booth of the open market place to the meagerly controlled open fire places in homes. The open fire place allows house flies to contaminate the meat during periods of low heat. Case hardening (extreme dryness on the outer surface) results from excessive heat and drying at the beginning of the process and because of large meat pieces that cannot dry throughout. The storage loss due to mold is not surprising since the relative humidity in most parts of Nigeria and other West African countries is high (~80%) during the rainy season (May to November). Also the finished products are packaged in burlap bags, transported in open trucks and sold in open retail trays or baskets in the market place. Under these conditions, the surfaces rehydrate and weevils and flies come in contact with the products. With the 200-500 pound bags of packaged commercial dried meat, a large percentage of the stored product is damaged by weevils. Regardless of whether the product is microbiologically spoiled or insect spoiled, the products are consumed. There are no quality standards or government established standard of identity to regulate the products once they are enroute to the market. Put in another perspective, even if the local health inspector intervenes, a poor villager might prefer to cook the spoiled meat at a higher temperature and ensure his family's meal than watch his family starve.

The objective of this study was to develop dried meat products which can be processed and stored without refrigeration, and at the same time maintain acceptable microbial levels and sensory properties. The products were prepared with natural ingredients common in the native African diet, in a way and level in line with good manufacturing practices. It was packaged in a fashion acceptable to the middle income group of Africa and will help in supplying meat to small communities on a regular basis. Valuable findings can be disseminated to the households where most drying operations occur and may be utilized to promote commercial production of dried meats. This technology could also be beneficial in the preserving of meats in the United States as energy needed for refrigeration becomes more costly.

CHAPTER II

REVIEW OF LITERATURE

I. MEAT DEHYDRATION PROCESSES

Early formal investigation on dried meat products were largely in search of answers to questions pertaining to the best grade of meat cuts and fatness of animals suitable for good products, best drying methods, best size of meat particles for drying and the optimum temperature for the selected process. Processes examined included vacuum rotary, plate vacuum, kettle cabinet, drum cabinet, rotar and drum air floatation (Hankins and Hetzer, 1947; U.S. Department of Agriculture, 1944). In some of these studies the raw meat containing about 4% to 18% fat was ground and precooked before drying. In others, the meat was dehydrated without prior cooking and, with and without prior grinding. With regards to the kettle cabinet method, the investigators pointed out that some factors which affected the drying rate were the fat content of the raw meat, the particle size of the drying meat, the cooking temperature in the kettle, the drying temperature and whether the meat was ground before or after the cooking process. They reported that meat ground after cooking dried almost twice as rapidly as that ground before cooking (U.S. Department of Agriculture, 1944). Also reported was that high fat percentage increased the time required for drying, although higher fat content of the raw meat would imply less moisture to be removed in drying. A suggested explanation was that the meat particles became encased in fat and thereby retarded moisture evaporation.

Of the methods studied, the vacuum rotary process was recommended as the most promising for prompt practical application. The investigators found that the process produced dried meat of good stability, flavor, rehydration capacity and vitamin retention (Hankins and Hetzer, 1947; Rice and Robinson, 1943; and U.S. Department of Agriculture, 1944). In general, the results of the investigations indicated that the quality, including the stability of dehydrated meat products depends largely on both the quantity and temperature of the drying air. Low-temperature dehydration, with the use of large volumes of air, was said to result in products with highly satisfactory keeping quality (U.S. Department of Agriculture, 1944). Also reported was that cooked meat dried more quickly than raw meat, and ground meat dried more quickly than unground meat. Cooked meat understandably should dry faster than raw meat since cooked meat has lost a portion of its original moisture and the proteins are dehydrated. Ground meat has greater surface area for moisture evaporation than unground meat; thus it is not surprising that it dries faster.

II. ENZYMES FOR MEAT TENDERIZATION

One of the characteristics highly desired in a meat product is tenderness. Fresh beef is aged between 14 to 21 days (depending on the temperature) in order to achieve maximum tenderness. In some cases the tenderness of a meat cut is improved by adding proteolytic enzymes such as papain, ficin or bromelain (Whitaker, 1978; and Hay et al., 1953). Ficin is obtained from the fig tree while bromelain is from pineapple. Papain is obtained from the fruits of Carica papaya which grows

in tropical climates. This enzyme is found largely in the milky latex of the green fruits, leaves, and the trunk of the tree (Balls et al., 1940; and Balls, 1941). Other proteolytic enzymes found in papaya latex include chymopapain and lysozyme, however papain and chymopapain are the principal proteases of this latex, with chymopapain higher in quantity (Reed and Underkofler, 1966). Plant proteases like papain, ficin and bromelain definitely hydrolyze the major proteins in the connective tissue of beef muscle. Ficin and papain hydrolyze not only the muscle protein but also substantial amounts of collagen and elastin. Most of the collagen is not attacked by these enzymes until a temperature of about 40° C has been exceeded. This is a requirement for collagen denaturation prior to papain or ficin hydrolysis (El-Gharbawi and Whitaker, 1963).

Among the three enzymes papain is most commonly used in the meat industry. The stability of papain in solution is good at pH 5 but drops off sharply at pH values below 3 and above 11. It is also quite stable at elevated temperatures in comparison with the other proteolytic enzymes. Its activity is reported to have dropped only by about 20% after an exposure to 70°C for 30 minutes (Reed and Underkofler, 1966; Moreau and Jankus, 1963). It has a broad specificity too. Papain is slowly inactivated by atmospheric oxygen. The levels of crude commercial papain which are useful for the tenderization of beef are in the neighborhood of 5 ppm. The regulations of the United States Food and Drug Administration (F.D.A.) no longer permit the use of crude papain in food products. It must be purified by an approved process before it is used. Hay et al., (1953) reported that there were no significant

differences in aroma and flavor between enzyme-treated and untreated meat cuts. However they pointed out that too high an enzyme concentration or too long a period of treatment would result in over-tenderization, mushiness and eventually in the formation of an undesirable "hydrolyzate" flavor. Rice and Robinson (1943) reported that treatment with papain reduced the riboflavin value in cooked meat samples.

III. THE APPLICATION OF SMOKE TO MEAT PRODUCTS

Smoking of meat and meat products was done originally to preserve the meat and increase its shelf-life (Arafa et al., 1979). It is known today that smoking affects both the color, surface texture and aroma of products in addition to their shelf-life (Ugstad et al., 1979; and Sink, 1979), but still the primary significance of smoking in developing countries is its preservative action (Hsu et al., 1979). More than 200 individual chemical compounds have been identified in the curing smoke (Gilbert and Knowles, 1975). Most common among these chemical compounds are carbonyls, carboxylic acids, phenols, alcohols, hydrocarbons and gases such as carbon dioxide, carbon monoxide and nitrous oxide (Daun, 1979). Investigators in this area recognize that the temperature of generation is of prime importance for the smoke quality; however, they do not agree on the optimum generation temperature for the active components--phenols, carbonyls and carboxylic acids--of curing smokes (Ugstad et al., 1979).

Smoke has both antioxidative and bactericidal properties. The antioxidative property is reported to be due to some high-boiling phenols such as 2, 6-diethoxy-phenol, while the bactericidal properties

are credited to a combined effect of heating, drying and chemical components such as formaldehyde, and acetic acid in addition to the high-boiling phenols (Tilgner et al., 1967; Radecki et al., 1975; Daun, 1979).

Investigations on the effect of smoke on the nutritive value of flesh food have strongly indicated that smoking causes some decrease in available lysine in the myofibrillar proteins (Randall and Bratzler, 1970; Chen and Issenberg, 1972; Inagami and Horri, 1966; Dvorak and Vognarova, 1965). Chen and Issenberg (1972) reported a 44% loss of available lysine in beef samples heated in smoke, but only a 15% loss in samples heated in air. Smoked meat showed some loss in thiamin, with negligible losses in niacin and riboflavin, but these losses could be attributed to the heating effect (Daun, 1979). The antioxidative effect should protect fat-soluble vitamins against oxidative degradation.

Polycyclic aromatic hydrocarbons and nitrosamines known to be carcinogenic have been found in smoked foods. The most common offender is 3, 4-benzopyrene (Wistreich, 1979; Daun, 1979). The actual amount of these compounds are found to be affected by the method of smoke generation, the form of smoke application (vapor or liquid), the length of smoking period and temperature of the smoke application (Potthast, 1978). Lowering the temperature of smoking decreased the amount of polycyclic aromatic hydrocarbons in the smoked food (Potthast, 1975, and Daun, 1979). Solubilization of smoke ingredients in water allows removal of some of the polycyclic hydrocarbons (Hollenbeck, 1979). The liquified smoke preparations, besides the reduction or elimination of potentially carcinogenic substances, offers the possibility of controlling concentrations

of desirable components. According to Fritz (1973) charcoal broiling of non-smoked foods resulted in similar levels of polycyclic aromatic hydrocarbons as found in smoked foods.

In developed countries the principal reason for the present practice of smoke processing is to impart a desirable flavor and color (Sink, 1979). Ruiter (1979) reported a strong indication of similarity between the reactions that lead to smoke color and the reactions between sugars and amino-components, known as the Maillard reaction. Such a reaction is greatly enhanced if the equilibrium relative humidity is about 65% to 70%. This corresponds to moisture contents of 12% to 15% in the surface layer of meat or fish. Ruiter (1979) suggested that the product surface should be moist enough to absorb smoke gases and dry enough to allow the smoke components to react on the surface before they diffuse into lower parts of the product. He reported that the color intensity of smoked food depends on the kind of wood used. The use of coniferous woods is supposed to lead to darker products than products treated with smoke from a hardwood fire. It is believed that the characteristic flavor of smoked food is mainly due to phenolic compounds in the smoke adsorbed on the surface of the food (Bratzler et al., 1969, and Daun, 1972). The phenols most associated with smoke flavor and color include guaiacol and 2, 6-diethoxyphenol (Daun, 1979).

IV. THE USE OF SALT IN MEAT PRODUCTS

Salt is a seasoning agent; hence it performs an essential flavoring function in meat and other food products. Salt aids in solubilization of the myofibrillar proteins--a desirable property in emulsified meat

products. In addition to its seasoning role, it controls texture and moisture levels in various foods including meat products. Wierbicki et al., (1954) reported that injection of beef muscle with solutions of sodium chloride increased the meat's water-holding capacity and tenderness. Meat can be dried to reduce its water activity below the minimum requirement of microorganisms, or hydrophilic chemicals can be added. Salt is one of the most effective agents for lowering water activity (Anonymous, 1980). By the virtue of its hydrophilic property, salt has served widely as a preservative or curing agent for centuries (Schaible and Davidson, 1941; Scott, 1957; Lawrie, 1966). Sodium chloride is stable and is considered to be more important than sodium nitrate in preventing the growth of the spores of putrefactive, anaerobic spoilage bacteria in canned meat (Stumbo et al., 1945). Reed et al., (1951) reported that 3.5% salt had the same effect as 0.2% sodium nitrate on heated Clostridium botulinum at pH 7.0. Baird-Parker and Fream (1967) worked with media containing salt concentrations from 0% to 10.3% at pH values between 7.0 and 5.0 and found that as the pH was lowered, the concentration of salt required to inhibit Clostridium botulinum decreased. They found that spores of Clostridium botulinum types A, B and E germinated at 10.3% salt but were unable to initiate vegetative growth. The initiation of growth by spore and vegetative cell inocula of Clostridium botulinum types A and B has also been prevented by adding 6 to 10% salt (Yesair and Cameron, 1942; Greenberg et al., 1959). The precise limiting concentration of salt depends on the germination medium, incubation temperature, strain tested and the number of spores used as inoculum. The combined effect of pH and salt concentration on

the initiation of growth by Clostridium botulinum spores may prove useful in reducing the botulism hazard of foods including meat products, since the prevention of spore development into vegetative cell prevents toxin production. Stern et al., (1980) found that 7% salt was inhibitory to Yersinia enterocolitica at 25°C, in brain heart infusion broth (BHIB) with 10^2 cells per milliliter incubated for 48 hours. The 7% salt added to BHIB lowered water activity to 0.945. Salmonella was also inhibited at water activity levels below 0.945 (Lee and Riemann, 1971), but many fungal pathogens survive for at least one week in highly concentrated salt solutions (Ekundayo, 1979; Dzawachiszwili et al., 1963).

The desirable functions of salt in processed food notwithstanding, there has been some controversy on the amount of salt added to food products. Such controversy is based on the evidence that populations with sodium intake between 70 to 350 milliequivalents per day have a low prevalence of hypertension while those with greater than 350 have markedly increased hypertension (Freis, 1976). Epidemiological data support a causal role for salt in hypertension; the higher the salt intake, the greater the prevalence of hypertension. Besides, populations that live on low salt diets, (less than 5 grams per day per person) have essentially no hypertension and no rise in blood pressure with age (Hegsted, 1978). Hegsted (1978) reported that salt intakes on the order of 30 grams per day per person were definitely toxic and elevated blood pressure rapidly. The relationship between salt intake and hypertension in epidemiological studies is complicated by other factors such as obesity, other dietary demands and sociocultural factors (Corbett et al., 1979).

V. EFFECTS OF PROCESSING AND STORAGE ON NUTRIENTS OF DEHYDRATED MEAT

Generally stated, the quantity of any particular nutrient in a given food depends on both compositional and environmental factors. With a processed product such as dehydrated meat, the environmental factors involve a complex interaction of the processing conditions, including equipment, temperature and storage, and the interaction of the different nutrients with each other. Thiamine, for instance, is much more sensitive when it is bound to protein than in the free state. Ascorbic acid stabilizes vitamin A, and in the presence of riboflavin, both ascorbic and folic acid were found to be much more sensitive to light (Karel, 1979). During dehydration, losses usually occur in nicotinic acid, riboflavin and thiamine in varying degrees. In the studies conducted by the U.S. Department of Agriculture (1944), the investigators examined the retention of different nutrients in dried meat. They reported that nicotinic acid and riboflavin losses were relatively small and that the most marked effect of dehydration processes was on the thiamine content. According to their results, the average losses in thiamine during the entire processing procedure were 43% and 53% for vacuum rotary and kettle cabinet methods respectively. The greatest loss occurred during the precooking period (Rice and Robinson, 1943). Samples exposed to large volumes of air and higher temperature but containing an antioxidant (0.03% of gum guaiac) was reported to show good thiamine retention. Phosphorus and iron remained fairly unchanged (U.S. Department of Agriculture, 1944). Pantothenic acid retained in dried beef was up to 68% (Rice and Robinson, 1943). The studies conducted by the U.S. Department of Agriculture (1944) showed

that thiamine was unstable at storage temperatures of 21.1°C and above, and unstable after long storage time periods even at lower temperatures. In their studies the product was practically devoid of thiamine after 8 weeks of storage at 43.3°C or at temperatures alternating between 10° and 43.3°C.

In some rat-feeding tests measuring the biological value of the protein in dehydrated meats, the average gain in weight of rats over 30 days, per gram of protein consumed, was 3.15 grams for beef with average digestive coefficient (proportion of protein excreted in the feces) of 88.7%, when the diet contained 10% dried meat. Dehydrated pork and mutton gave average gains of 3.35 grams and 3.2 grams respectively with digestive coefficients of 92% and 90.9% respectively (U.S. Department of Agriculture, 1944). It may be pointed out that the quantity of connective tissue in the raw meat, the maximum temperature of processing and the duration of exposure to such temperature may affect the biological values obtained. In general the results of previous studies indicate that the protein in dehydrated pork, beef and mutton is relatively high in nutritive value when properly prepared from suitable raw material.

VI. REHYDRATION OF DRIED MEAT

It is generally believed that with other factors kept constant, the greater the capacity of a sample of dried meat to absorb and hold moisture, the closer it will be to fresh meat with respect to certain elements of palatability. Involved in the property of holding water is the extent to which the native structure of the molecules in the product is retained. Hankins and Hetzer (1947) worked with dehydrated pork processed in a vacuum

rotary dryer. The protein content of their samples ranged from 64.8% to 55.5% with fat content ranging from 26.5% to 39.4%. They reported rehydration values varying from 38.5 grams (per 100 gram of dehydrated sample) for samples lowest in fat to 16.6 grams for the samples highest in fat. The corresponding protein-fat ratios were 2.34:1 and 1.41:1 respectively. As the protein-fat ratio was widened by removing the fat in increasing amounts by suction, the observed rehydration values increased correspondingly from 7.4 to 37.3 grams per 100 gram sample (Hankins and Hetzer, 1947; and U.S. Department of Agriculture, 1944). Particle size is another factor that affected rehydration. Rehydration values varied inversely with the size of the meat particles. Such variation might be explained by the difference in surface area, since a given weight of product consisting of small particles would possess more surface for moisture absorption, all other factors being constant. These investigators reported that the protein factor had more effect on rehydration than the particle size factor. Also investigated was the influence of processing methods on the property of rehydration. They found that the drum method of precooking meat for dehydration caused extreme denaturation of the protein, and therefore, resulting products did not compare favorably with the products processed by the kettle method in rehydration capacity. Vacuum rotary and freezing cabinet methods resulted in products of relative low moisture, and unquestionably higher values of rehydration (Hankins and Hetzer, 1947). These investigators concluded that high protein and low fat content or a wide protein-fat ratio, small particle size, and relatively low drying temperatures contributed to high rehydration values. Drum-air flotation,

kettle-air rotary and kettle cabinet processes yielded products with low rehydration values.

VII. PACKAGING, STORAGE AND PALATABILITY OF DRIED MEAT

The main objective of drying meat is to enable it to remain stable and acceptable without refrigeration. Previous investigators have found that the stability of dehydrated meat depends on the packaging material and the temperature of storage, with other conditions being constant (U.S. Department of Agriculture, 1944; Whitmore et al., 1948). These investigators examined the use of different materials including cans, paper and metal-foil packages. They also examined different atmospheric conditions including air, nitrogen and vacuum as a means of improving stability of dried meat products. They reported that properly sealed cans fulfill the packaging requirements of dehydrated meat better than any other tested container. As for the envelope-type of containers, the best substitutes for cans were the lead-foil bags. Concerning the atmospheric condition inside the containers, they found that when the dehydrated product was of good quality, samples air-packed in cans were practically as good as those packed in vacuum or in nitrogen in the same kind of containers. These investigators recommended that containers to be used for dehydrated meat should protect against light and vermin including insects, be able to withstand rough handling and temporal immersion in fresh and salt water. Such containers, they stressed, should exclude air, moisture-vapor, and should be impermeable to fat and resistant to the transmission of foreign substances including those of odors and flavor.

In the studies conducted by the U.S. Department of Agriculture (1944), dehydrated meat stored in metal cans at 43.3°C and 57.2°C developed reddish color. Perceived with the reddish coloration are flavors which their meat judges described as "overcooked," "scorched" and "browned" between 6 to 12 months of storage. The changes in color and flavor appeared in various types and qualities of meat in different kinds of packs. When stored in cans at moderately low temperature, the products were reported as having excellent keeping quality. The samples stored at room temperatures had only a little change in flavor or color after 12 months of storage. The color changes together with associated changes in the degree of acidity lead the investigators to the suggestion that high temperature storage resulted in protein breakdown (U.S. Department of Agriculture, 1944).

Whitmore et al., (1948) stated that dehydrated beef and pork would remain edible for six months packed in an atmosphere of air, in nitrogen or in vacuum, in metal cans at 57.2°C. They reported that samples were palatable at the end of 12 months storage at 43.3°C and at room temperature. The studies conducted by the U.S. Department of Agriculture (1944) indicated that larger particle size and higher fat content appeared to contribute to palatability. Palatability scores of dehydrated meat increased with increased additions of vegetable and seasonings in stews. The product packed in vacuum maintained palatability slightly better than that packed in nitrogen, and that packed in nitrogen was slightly better than the samples packed in air. Palatability decreased as storage time or storage temperature increased. Treatment of the meat

with about 0.08% gum guaiac during precooking prevented the development of rancidity in dehydrated meat.



CHAPTER III

MATERIALS AND METHODS

The top and bottom rounds of United States Commercial grade cattle were purchased from Lays Meat Packing Company, Knoxville, Tennessee. This meat was cut into pieces of about 3 X 4 X 5 cm after trimming off the external and seam fat layers. Samples were randomly taken for the analysis of initial microbial load, total fat, volatile fatty acids, thiobarbituric acid number and titratable acidity. Fresh, mature, partially ripe papaya fruits were purchased from a local supermarket. These fruits were washed with tap water and their seeds removed and discarded. The unpeeled, seedless fruits were diced and ground into a slurry using a Hobart Food Chopper. The pH of the slurry was determined with an electronic pH meter (Fisher Model 600).

Meat curing solutions of non-iodized salt and papaya slurry in tap water were prepared in two-liter, food-grade plastic pails with covers. The amount of salt in the solutions was varied from 0% to 10% (based on the weight of water), in increments of 2. The amount of papaya slurry was varied from 0% to 25% in increments of 5. All combinations of salt and papaya levels resulted in 36 different treatments. The pH of these treatment solutions were also determined using the electronic pH meter. About two pounds of the fresh meat pieces were introduced and stirred into each solution. The containers were covered and left at room temperature ($22.7^{\circ}\text{C} \pm 1.4$) for 48 hours. At the end of 48 hours of curing, the pH of the curing solution was determined as before. Samples of each treatment were separately rinsed in tap water to rid them of papaya particles. As

the samples were rinsed, odor perceptions were recorded. Each treatment level was spread on stainless steel drying racks and placed in an Alkar Food Processing Oven for drying. The oven was equipped with automatic temperature and humidity controls as well as wood smoke generation capability. The meat samples were dried at an isothermal smoke house temperature of 48.9°C. Wood smoke was applied to the product for one hour after a 30 minute drying period. Samples were removed at five hour intervals from the treatment which had neither salt nor papaya added (Salt 0%; Papaya 0%), for water activity determination. The smoke house operation (drying) was stopped after a water activity of 0.5 was reached (over 45 hours of drying at 48.9°C). At that time the smoke house was opened and the product left on the drying racks for about one hour to cool to room temperature. The cooled products were packed by treatments in polyethylene bags which had no air tight seal. These bags were stored at room temperature (23.9°C) for eight weeks. Samples were removed at the end of four weeks and examined for surface mold growth. These samples were then frozen in liquid nitrogen, powdered with a Waring blender and analyzed for volatile fatty acids, thiobarbituric acid number (TBA), percentage moisture, pH values and titratable acidity. At the end of eight weeks storage, the remainder of samples in all treatments were analyzed for all parameters stated above. The above procedure and stated analyses were done in duplicate. The entire experiment was replicated once with a different supply of fresh meat from the same packing company.

I. FINAL PRODUCT

The data obtained in all analyses were examined, and a treatment level of 10% salt and 10% papaya was chosen for the preparation of a final product for human consumption. The final product was prepared with a fresh supply of ingredients as stated above. Some pieces were dried in a similar way as the treated product. These samples were used as the control sample in the sensory comparison of the experimental product. Dried and cooled products were packed in polyethylene bags and stored for four weeks at room temperature (23.9°C). The experimental and control samples were analyzed for volatile fatty acids, TBA number, percentage moisture, titratable acidity and pH value. The actual percentage of salt in the experimental product as produced was determined. After sensory evaluation all samples were analyzed for the actual level of salt.

II. WATER ACTIVITY (A_w)

The A_w of some samples were determined during the drying operation by the vapor pressure manometric method as recommended by Labuza et al., (1976). The instrument was calibrated within the range of 0.33 to 0.97 using saturated solutions of magnesium chloride-hexahydrate, sodium nitrite, sodium chloride and potassium sulfate. Fifty ml portions of each solution contained in 100 ml round bottomed ground neck flasks were used. For the vapor pressure manometer, the level of oil (Apiezon B oil) in the manometer responds to the vapor pressure exerted by the measured sample, thus the difference in the height (ΔH_1) of the oil levels of the manometer at the temperature of equilibration gave the vapor pressure of

the sample and any gas or volatile lost by the sample (Labuza et al., 1976). The partial vapor pressure due to gas or volatiles from the sample was found by taking another reading (ΔH_2) when the stopcock over the sample was closed and the one over the desiccant was opened. The actual vapor pressure of the sample was obtained as the difference between the two readings ($\Delta H_1 - \Delta H_2$). The A_w was calculated from the ratio of the vapor pressure of the sample to that of pure water at the same temperature. A chart of the vapor pressures of pure water at different temperatures was obtained. The calculated A_w values observed for the saturated salt solutions, were plotted against the literature values for the same set of salts (Labuza et al., 1976) and a calibration curve obtained (Appendix 1). Then the meat samples removed from the smoke house during the drying process were sliced into flakes of about 1 mm thick. Thirteen gram samples of these flakes were used in determining the A_w reached at each drying time interval--for the Salt 0%; Papaya 0% treatment. The vapor pressure of the samples was determined in a similar manner as the saturated salt solutions, and the A_w calculated from the values as stated before. Using the calculated A_w values, the actual (corrected) A_w values were obtained from the calibration curve. The corrected A_w values were plotted against the drying time. From this curve the length of drying time necessary to bring all samples below an A_w value of 0.60 was estimated and all drying operations were carried out for such a period of time.

III. TOTAL LIPID

Only the fresh meat and final dehydrated products were extracted for total lipid. This extraction was done by a modified procedure of

Ostrander and Dugan (1961). A 15 g powdered sample was blended in a Waring blender with 130 ml of methanol for five minutes at low speed. Sixty-five ml of chloroform were added and the mixture was blended for another five minutes. An additional 65 ml of chloroform was added and blended for 20 seconds. Then 1.5 g of zinc acetate, dissolved in 65 ml of deionized water, were added to the mixture and blended for ten seconds. This mixture was filtered through a Whatman No. 1 filter paper in a Buchner funnel under suction. The residue and used filter paper were put into the blender. The funnel was wiped with Kleenex tissue and the tissue was added to the blender contents. All blender contents were blended with 100 ml chloroform for 2.5 minutes. This mixture was filtered through another Whatman no. 1 filter paper in a Buchner funnel under suction. The blender jar was rinsed with 75 ml of chloroform which also were filtered as before. All filtrates were combined in a 500 graduated cylinder. The suction flask was rinsed in turn with 25 ml of methanol and chloroform and the rinse added to the filtrate. The head space of the filtrate was flushed with nitrogen and the filtrate stored at 4°C until the methanol and chloroform layers were distinctly separated. The volume of the chloroform layer was recorded. All layers were transferred to a 500 ml separatory flask and the distinct layers re-established overnight. The chloroform layer (bottom) was drained into a Erlenmeyer flask. Ten ml of the chloroform extract were pipetted into each of two dry, tared 50 ml beakers. The contents of these beakers were evaporated overnight under the hood and dried at 70°C for six hours in vacuum oven. The beakers were cooled in a dessicator and reweighed within one hour. The average weight of lipid in any particular sample was calculated from the data obtained (Appendix 2).

IV. VOLATILE FATTY ACIDS

All thirty six treatments were studied for volatile fatty acids. For the extraction of volatile fatty acids, 50 grams of powdered, fresh meat samples and 25 grams of powdered, treated products were used per treatment. Each sample was thoroughly suspended in 150 ml of distilled water. The proteins were precipitated with 25 ml of 1 N sulfuric acid and 40 ml of 20% phosphotungstic acid. Fifty ml of distilled water were added at this point to make a total of 265 ml of liquid. The resulting mixture was shaken vigorously and filtered through a 24-cm rapid flow filter paper. From this point the procedure recommended in section 18.050 of AOAC (1980) was followed. One hundred fifty ml of filtrate were steam distilled under constant volume conditions (Ubbaonu et al., 1980). Two hundred ml of distillate were collected in a volumetric flask, transferred to a 500 ml flat bottom, 24/40 groundneck flask and were neutralized with 0.1 N sodium hydroxide solution using phenolphthalein indicator. An excess (1.0 ml) of sodium hydroxide was added. The resulting pink solution was evaporated to dryness on a vacuum rotary evaporator at 47°C. The volatile fatty acids present were liberated from the dry crystals of their sodium salts using 2.0 ml of 0.5 N dichloroacetic acid in acetone. The solution was diluted to 5 ml volume with acetone. Then 0.70 mg of methylheptylketone contained in 0.5 ml acetone solution was added. This was the internal standard used for the gas liquid chromatograph (GLC) analysis. The resulting solution was collected in a 7 ml screw cap vial with teflon septum, and stored in refrigerator until GLC analysis.

The fatty acids present were identified by comparing the retention time and relative retention time (relative to internal standard) of the chromatograph peaks of the sample with those of a standard solution containing 7.354 mg of acetic acid, 0.4962 mg of propionic acid, 0.9870 mg of butyric acid and 0.70 mg of methylheptylketone in 5.5 ml solution of acetone (Appendix 3). Analysis was done on a Bendix gas liquid chromatograph, model 2500, equipped with a flame ionization detector, Dohrman recorder and an electronic integrator (Shimadzu Chromatopac E--1A). The column was 1.83 M X 6.35 mm glass packed with 10% FFAP, 80/100 Gas Chrom Q. The instrument was set at detector temperature of 160°C, injector and transfer temperature of 160°C, isothermal oven temperature of 135°C and at an attenuation of 200. Nitrogen (carrier gas), hydrogen and air flow rates were 35 ml/minute, 40 ml/minute and 40 ml/minute respectively. Three microliters of the standard solution were injected and the peaks of the chromatogram identified. Two more injections were made and the retention time and response factor of each acid were obtained by the electronic integrator. Three microliters of each sample solution were injected in turn and peaks identified and quantitated as mg of fatty acid per 100 g of dried meat as produced. Corrections for distillation loss and portion of extract distilled were made on the values read from the integrator print-out, to obtain actual experimental values (Appendix 4).

V. THIOBARBITURIC ACID (TBA) NUMBER

The TBA number of samples from all treatment levels were determined by the distillation method as recommended by Tarladgis et al., (1960). A stock solution of 1, 1, 3, 3-tetraethoxypropane containing 1.0×10^{-3} M

of the solute was prepared by dissolving 0.2204 g in 1 liter of water solution. Five ml of the stock solution were diluted to 50 ml solution to obtain an intermediate solution containing 2.204×10^{-5} g/ml of solution. Working solutions ranging from 1.0×10^{-8} M/5 ml to 8.0×10^{-8} M/5 ml were obtained by diluting appropriate volumes of the intermediate solution to 50 ml solution. For instance 1 ml of the intermediate solution diluted to 50 ml gave 1.0×10^{-8} M/5 ml and 7.0 ml of intermediate solution diluted to 50 ml gave 7.0×10^{-8} M/5 ml.

Five ml of each working solution were pipetted into separate 20 ml glass test tubes loosely covered with glass marble. Five ml of 0.02 M solution of 2-thiobarbituric acid in glacial acetic acid were added and the contents mixed by rotating. A tube of distilled water-TBA reagent blank was also prepared. All tubes and contents were dipped into boiling water for 35 minutes. At the end of 35 minutes, all tubes and contents were cooled in cold tap water for 10 minutes. The optical density (absorbance) of each concentration level was read against the blank solution at a wavelength of 538 nm using a Hitachi double beam spectrophotometer. A calibration curve for quantitation was obtained by plotting the observed absorbance values against the known molar contents in the 5 ml solution used (Appendix 5).

Fifteen grams of the powdered product were weighed into a Kjeldahl flask. Ninety eight ml of distilled water and 2 ml of approximately 4 N hydrochloric acid solution were added. A few boiling glass beads were dropped in, and the mixture shaken up. The flasks were assembled on Kjeldahl distillation equipment and the mixture distilled. Fifty ml of distillate were collected. Five ml portion was taken from each

distillate and mixed with 5 ml of 0.02 M TBA-reagent in a 20 ml test tube, loosely stoppered with glass marbles. Each sample was done in duplicate. From this point the samples were taken through the same procedures carried out for the standard 1, 1, 3, 3-tetraethoxypropane solution stated above. The observed absorbance (optical density) for each sample was recorded.

The percentage recovery of malonaldehyde with the Kjeldahl distillation equipment available was also determined. In this determination, 5 ml of the intermediate solution (5.0×10^{-8} M) of 1, 1, 3, 3-tetraethoxypropane were pipetted into each of three Kjeldahl flasks. Each of these was taken through the same procedures as the samples. The absorbance of each replicate was measured and recorded. The molar quantity of malonaldehyde (equivalent to 1, 1, 3, 3-tetraethoxypropane) in the 5 ml portion used, was read from the calibration curve (Appendix 5). Then the total molar quantity in the 50 ml distillate collected was calculated. This was the quantity recovered. The ratio of the recovered quantity to the 5.0×10^{-8} M used, was multiplied by 100 to obtain the percentage recovery. The TBA number (mg of malonaldehyde per 1000 g of sample) of each product sample was calculated by multiplying the absorbance of that particular sample by a constant K, whose value was obtained from the standard calibration curve (Appendix 6).

VI. TITRATABLE ACIDITY AND pH VALUES

The titratable acidity was measured by the glass electrode method as recommended in section 22.061 of AOAC (1980). A Fisher Accumet pH-meter model 600 was used. The instrument was standardized within the range of pH 4.0 and pH 9.0. Five grams of powdered samples were used

for the products while 10 grams were used for fresh meat. The samples were stirred into 100 ml of distilled water contained in 200 ml beakers. The pH of each sample was measured and recorded before titration with 0.1 N sodium hydroxide solution was started. The volume of the standard sodium hydroxide solution required to reach pH 8.1 was recorded. From such values the milliequivalent (mEq) of sodium hydroxide required for 100 grams of a sample was calculated and that was the titratable acidity value for that sample.

VII. PERCENTAGE OF SALT (NaCl) IN THE DEHYDRATED PRODUCT

The actual level of salt in the final product was analyzed by the volumetric method as recommended in section 18.035 of AOAC (1980). Each sample was analyzed in duplicate. Two grams of the powdered product were weighed into a clean, dry 500 ml Erlenmeyer flask. Ten ml of 0.4994 N solution of silver nitrate were added, and the mixture shaken to mix. Fifteen ml of concentrated nitric acid was added and the mixture boiled on a hot plate until the meat dissolved. A saturated solution of potassium permanganate (KMnO_4) was added by a Pasteur pipet with boiling after each addition until the permanganate color disappeared. Addition of KMnO_4 was stopped when a clear sample solution was observed. At this point 25 ml of deionized water were added and the sample boiled for 5 more minutes. Then the sample was removed from the hot plate and allowed to cool. The cooled sample solution was diluted to 150 ml with deionized water. Twenty five ml of diethylether and 5 ml of Ferric indicator $[\text{FeNH}_4(\text{SO}_4) \cdot 12 \text{H}_2\text{O}]$ were added. The sample was titrated with 0.0998 N ammonium thiocyanate solution until a permanent light brown end point. Spiked

samples of unsalted dried meat were also analyzed in the same manner in order to find any probable correction factor. The volume of ammonium thiocyanate required to reach the end point was multiplied by its normality to obtain the milliequivalents of the excess silver left after a reaction with the salt in the sample. The milliequivalent (mEq) of salt in the 2 g sample analyzed was found from the difference between the added mEq of AgNO_3 and the mEq of ammonium thiocyanate used in titrating the excess silver. The values obtained for the samples were used to calculate the actual percentage of salt in the product (Appendix 7).

VIII. PERCENTAGE PROTEIN

The protein content was analyzed by the official method as recommended in section 2.057 of AOAC (1980). About 0.9 g powdered samples were used for the products while 2 g powdered samples were used for fresh meat. Each sample was weighed using a filter paper, and both the filter paper and sample were dropped into a Kjeldahl flask. Two filter papers without meat sample were folded into two Kjeldahl flasks. These served as the blank set. One Kel-pak (containing 0.7 g HgO and 15 g K_2SO_4) and 25 ml of concentrated sulfuric acid were added into each flask. All flasks and contents were assembled and heated on the Kjeldahl digestion equipment until clear solutions were obtained. All solutions were allowed to cool below 25°C and 200 ml of distilled water were added to each flask. Then 85 ml of a mixture containing 60 ml of 50% sodium hydroxide and 25 ml of 8% sodium thiosulfate solution were added to the contents of each flask. A few zinc metal granules were dropped into each flask and all flasks were assembled for distillation of contents.

The distillate of each flask was collected in a 500 ml graduated Erlenmeyer flask which contained 50 ml of 4% boric acid and six drops of methyl red indicator. Distillate was collected in each flask up to the 200 ml mark. All distillates were titrated with 0.1 N hydrochloric acid to an orange-pink end point. All titration values were corrected for the blank. The percentage protein was calculated with an appropriate formula using a conversion factor of 6.25 g protein per gram of nitrogen liberated (Appendix 8). The percentage of moisture in the product was determined as recommended in section 24.002 of AOAC (1980).

IX. SENSORY EVALUATION

The chosen experimental product (10% papaya and 10% NaCl) and a control product (only dried beef) were separately presented to a consumer panel of 64 members for acceptability rating on an eight-point hedonic scale. A score of one on the scale implied "disliked extremely" while a score of eight implied "liked extremely." Products were presented both as plain boiled pieces of meat and as pieces of meat in a Nigerian traditional (Egwusi) soup (Appendix 9). The panel members were asked to score each sample on its own merit of acceptance and to write under each sample any sensory perception which influenced their rating for that sample. Members were also requested to state how much they would be willing to pay for one pound of the experimental product and one pound of the control product given that one pound of fresh beef is sold at \$2.00/pound at the supermarket.

X. STATISTICAL ANALYSIS

The variance of all fatty acids, TBA number, titratable acidity, pH values and moisture content with treatment was analyzed using the "Proc GLM" program prepared by the Statistical Analysis System (SAS), (Barr et al., 1979). For each dependent variable an analysis of variance was run with a five term polynomial fitted for independent variables of interest. Non-significant terms were deleted to provide final models presented graphically in the figures.

XI. REHYDRATION OF PRODUCT

Twenty four pieces of the experimental product were separately weighed and tagged. All were put into a cooking vessel with enough water to keep all pieces under water. The samples were heated and boiled for 120 minutes. A set of three pieces was withdrawn from the vessel at intervals of 15 minutes and reweighed. The percentage of water absorbed (gain in weight) by each piece was calculated. The average value of absorbed water for each set at the intervals was calculated. The mean values were plotted against the time of boiling to obtain a rehydration curve.

CHAPTER IV

RESULTS AND DISCUSSION

I. TREND OF WATER ACTIVITY (A_w) OF CURED BEEF CUBES
DURING AN ISOTHERMAL DRYING PROCESS

The trend of A_w of the cured beef cubes during drying, as measured in the zero-salt, zero-papaya treatment level is shown in Figure 1. Before the drying operation, the A_w of the meat samples in this treatment level was 0.99. These samples lost water rapidly during the first ten hours of the drying process to an A_w of 0.85. After ten hours of drying, the rate of water loss decreased considerably for the next eighteen hours of the drying process. This is illustrated by the decrease in the slope

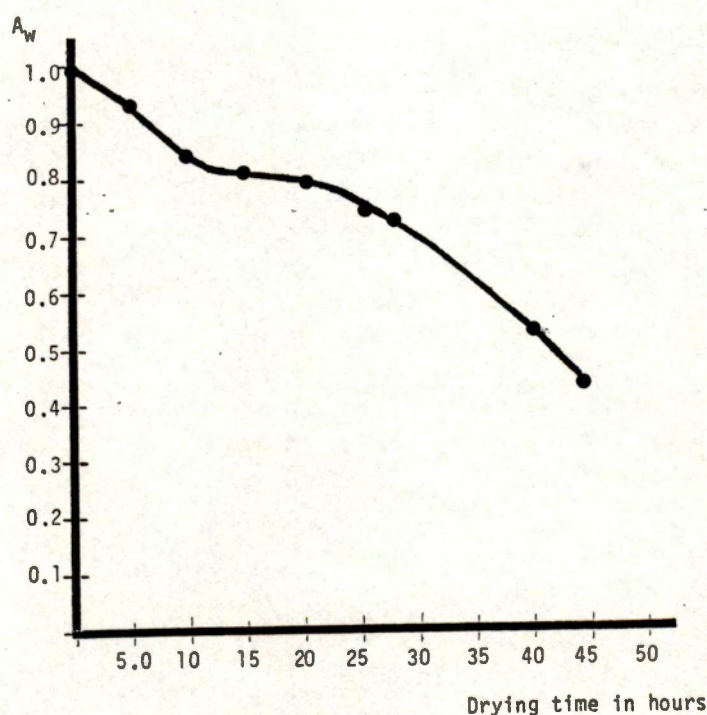


Figure 1. Drying curve for cured beef products at 48.9°C smoke house operation.

of the curve between 10 hours and 28 hours of drying as compared to the slope of same curve between zero hour and 10 hours. At 28 hours of drying the A_w was 0.72. After twenty eight hours of the drying process, the rate of water loss increased again and A_w value of 0.54 was achieved in 40 hours of drying. A water activity value of 0.43 was achieved by drying the samples for 44 hours at 48.9°C in the smoke house. Since products cured in zero-salt solution showed A_w values of about 0.54 at 40 hours of drying, it is assumed that the products cured in solutions containing salt had A_w values below 0.54 at 40 hours of drying. This would be expected since salt, by virtue of its hydrophilic property, is one of the most effective agents for lowering A_w (Anonymous, 1980). Even without any additional reduction of A_w by the addition of salt, the A_w of 0.54 achieved at 40 hours of drying was sufficient to check microbial growth since the range of A_w over which microbial growth has been demonstrated was from above 0.99 to about 0.65 (Scott, 1957; Northolt et al., 1979). There were variations in size and shape of the samples which could affect the water activity of the particular sample used in the measurement but such variations were not expected to affect the measured data significantly.

II. THE EFFECT OF SALT AND STORAGE TIME ON THE pH AND TITRATABLE ACIDITY OF CURED AND DRIED BEEF

The analysis of variance (Appendix 10) for the pH of the cured and dried meat indicates that neither the amount of salt added to the curing solution, nor the storage time of the dried meat product, affected the final pH of the product significantly ($p < 0.05$). This would imply that

the observed pH of the cured and dried beef should be stable if conditions of processing (raw materials and procedures) and the conditions of storage were constant.

The analysis of variance also indicates that salt significantly affected the pH of the curing solution before the curing process ($p < 0.01$), and the pH of the resulting solutions after 48 hours of curing ($p < 0.05$) (Table 1).

Table 1. Means and standard deviations of the pH of curing solutions before and after 48 hours of curing as affected by salt levels.

Salt levels	Initial pH of curing solution	pH of solution after 48 hours of curing
0%	6.29 $\pm$ 0.65	4.80 $\pm$ 0.34
2%	5.85 $\pm$ 0.73	4.83 $\pm$ 0.30
4%	5.81 $\pm$ 0.70	4.78 $\pm$ 0.27
6%	5.83 $\pm$ 0.79	4.76 $\pm$ 0.21
8%	5.69 $\pm$ 0.82	4.92 $\pm$ 0.33
10%	5.57 $\pm$ 0.90	5.10 $\pm$ 0.35

Salt effect on the observed pH of the curing solutions is further illustrated by the plots of pH against the added amount of salt (Figure 2).

These curves indicate that the added salt in the curing solution decreased the pH of the solutions before the meat samples were added to them; but after 48 hours of curing, the solutions with higher salt levels had higher pH values. The decrease in pH values of initial curing solution

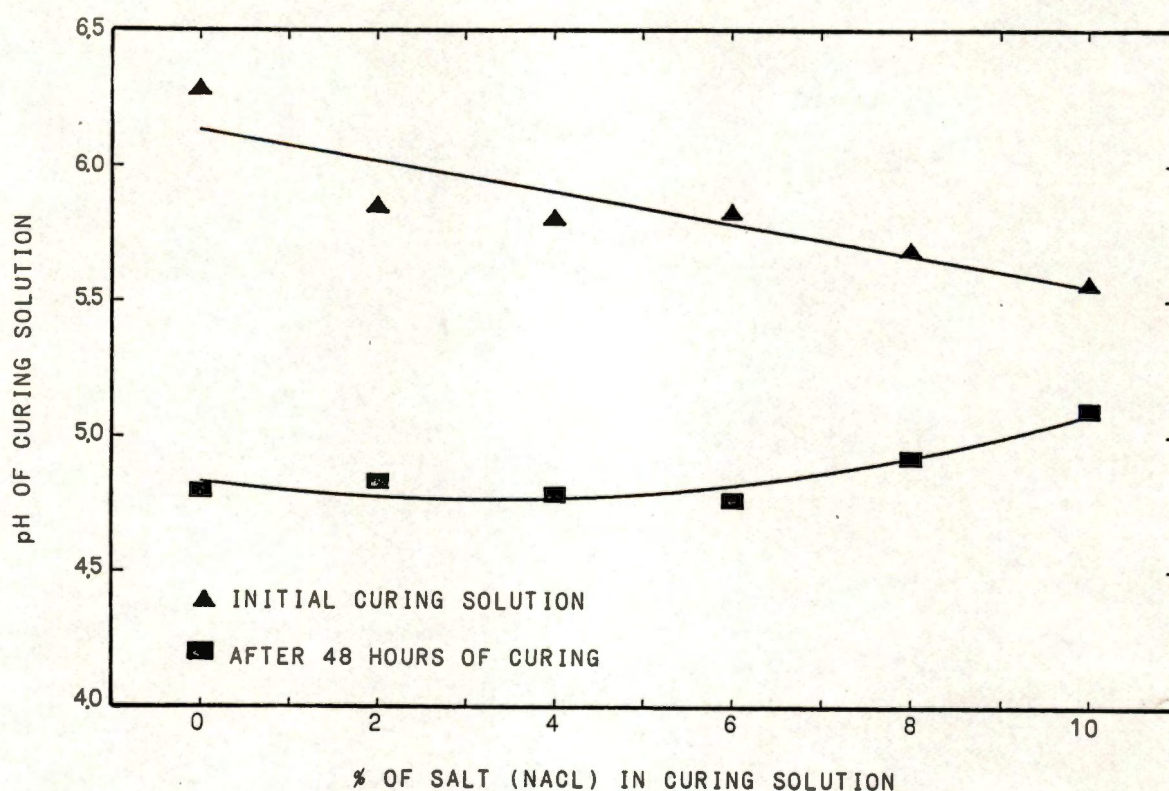


Figure 2. Effect of salt on the pH of curing solutions--before curing (initial) and after 48 hours of curing.

caused by salt, would not be expected unless the salt used had some acidic contamination. As for the increased pH values observed in solutions of higher salt levels after 48 hours of curing, one explanation could be that higher salt levels controlled or minimized the fermentation of the raw meat hence limited the production of lactic and fatty acids which could have lowered the pH values.

The titratable acidity of cured and dried beef was affected by both salt levels and storage period ($p < 0.001$) as indicated in the analysis of variance table for titratable acidity (Appendix 10). Means and standard deviations for salt treatment effect on titratable acidity are shown in Table 2.

Table 2. Means and standard deviations of the titratable acidity of cured and dried beef as affected by salt levels and storage time.

Salt levels	After 4 weeks storage	After 8 weeks storage
0%	37.11 $\pm$ 4.72	40.32 $\pm$ 7.63
2%	38.99 $\pm$ 8.81	43.20 $\pm$ 7.01
4%	39.54 $\pm$ 6.34	39.22 $\pm$ 6.40
6%	34.88 $\pm$ 6.06	39.89 $\pm$ 6.42
8%	31.67 $\pm$ 5.05	36.11 $\pm$ 5.45
10%	30.65 $\pm$ 4.43	31.11 $\pm$ 4.12

These effects were further illustrated by separate plots of the titratable acidity values against the levels of salt added to the curing solution for the two storage periods (Figure 3). These curves show that at any given level of salt in the curing solution, cured and dried beef had higher titratable acidity after 8 weeks of storage than it had after 4 weeks of storage at room temperature (23.9°C). The curves showed a slight rise towards 2% salt level and dropped down between 4 to 10% salt. This trend of the curve indicated that maximum titratable acidity values in cured and dried beef was achieved with 2% salt (based on weight of water) in the curing solution, and that titratable acidity decreased with increased level of salt in the curing solution beyond 2%. The decrease of titratable acidity with increased salt level could be explained by the control of microbial growth, specifically putrefactive anaerobic spoilage bacteria (Stumbo et al., 1945) in the raw meat during the curing process by higher salt levels. Such growth could have increased acid production in the

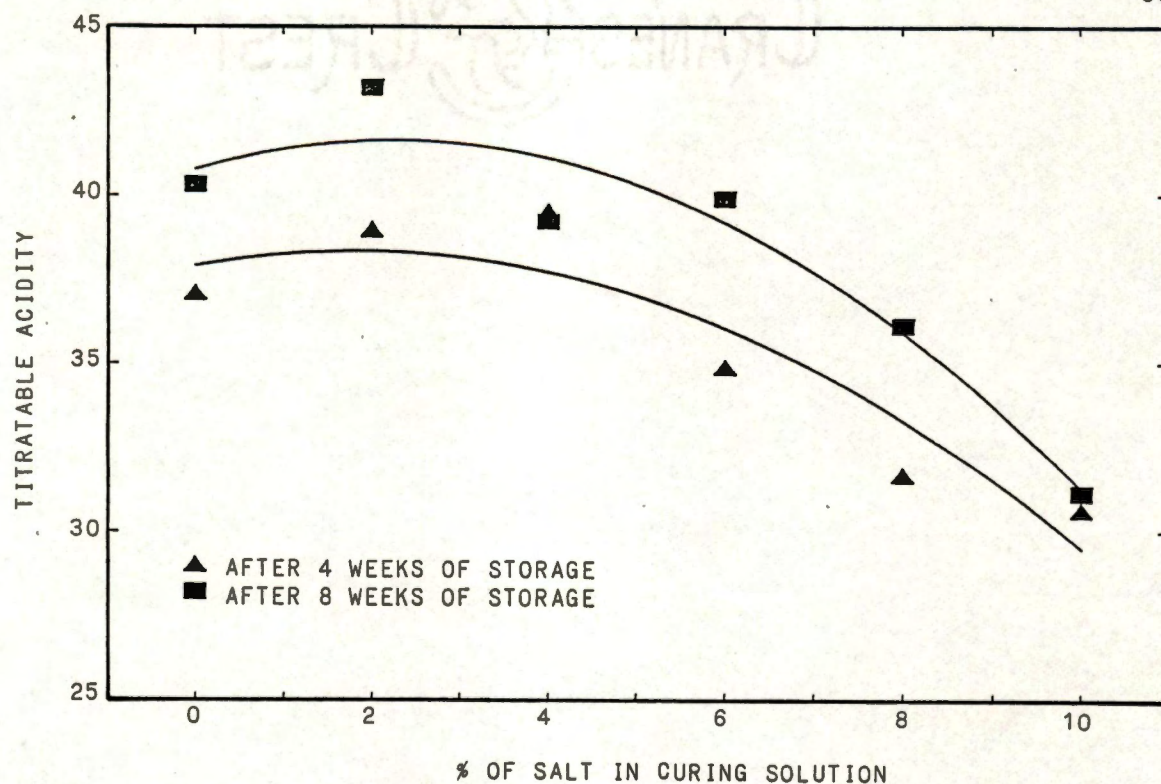


Figure 3. Effect of salt on the titratable acidity of cured and dried beef cubes.

meat with low salt content with a resultant high titratable acidity value. This view is consistent with the finding of Castro-Espinoza (1982) that samples of this product which had more than 4% salt had less than 10/g of psychrophiles, coliforms, c. perfringens, s. aureus, anaerobes, lactics, streptococci, yeasts and molds after one month storage at approximately 27°C.

III. THE EFFECT OF SALT LEVEL AND STORAGE TIME ON THE VOLATILE FATTY ACIDS OF CURED AND DRIED BEEF CUBES

In this study three volatile fatty acids were identified in cured and dried beef cubes. These acids were acetic, propionic and butyric

acids (Figures 4a, 4b, 4c, and 4d). These chromatograms indicated that the principal effect of salt was on the quantities of the acids rather than on the acid types, since all salt levels had the same acids. The analysis of treatment variation effects on acids are shown in Appendix 10. Significant salt effects were observed for all three acids. The levels of significance ranged from $p < 0.05$ for acetic and butyric acids to $p < 0.001$ for propionic acid. Storage time significantly ($p < 0.001$) affected acetic and butyric acids but had no significant effect on propionic acid.

The means and standard deviations of the observed values of acetic acid at various salt levels are shown in Table 3. The data in this table show the observed salt and storage effects while the trends of such effects are illustrated by the plots of the observed acetic values against salt levels for the two storage periods (Figure 5). The curves shown in Figure 5 indicated that the quantity of acetic acid in cured and dried beef decreased linearly. At any given salt level, the product had a higher quantity of acetic acid after 4 weeks of storage than after 8 weeks of storage at room temperature (approximately 23.9°C).

The mean and standard deviations of propionic acid at the studied salt levels are shown in Table 4. These values together with the curve obtained by plotting the amount of propionic acid versus the levels of salt (Figure 6) showed that quantity of propionic acid decreased with increasing levels of salt in the curing solution.

The mean and standard deviations of butyric acid in this product at the levels of salt and storage time studied are shown in Table 5. The acid values in this table were plotted against the corresponding

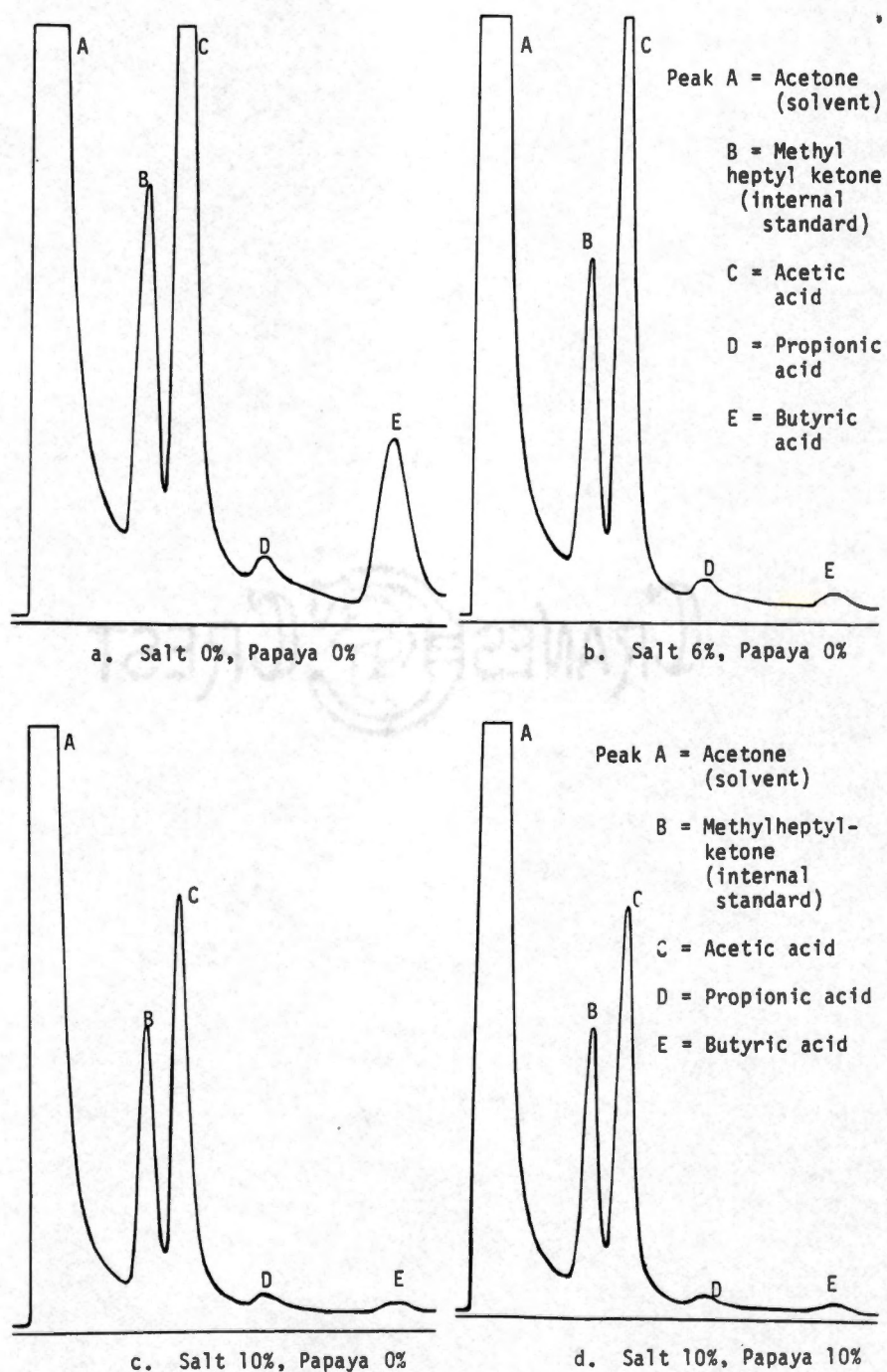


Figure 4. Chromatograms of volatile fatty acids in cured and dried beef cubes.

Table 3. Means and standard deviations of acetic acid in cured and dried beef cubes at different salt levels and storage periods.

Salt levels	After 4 weeks storage		After 8 weeks storage	
	 mg acid/100g sample.			
0%	266.61	+ 247.13	168.95	+ 162.76
2%	286.18	+ 193.89	142.93	+ 122.08
4%	195.38	+ 115.62	134.47	+ 91.79
6%	121.45	+ 49.73	100.23	+ 48.71
8%	90.42	+ 25.27	75.89	+ 33.66
10%	79.87	+ 35.46	60.83	+ 27.47

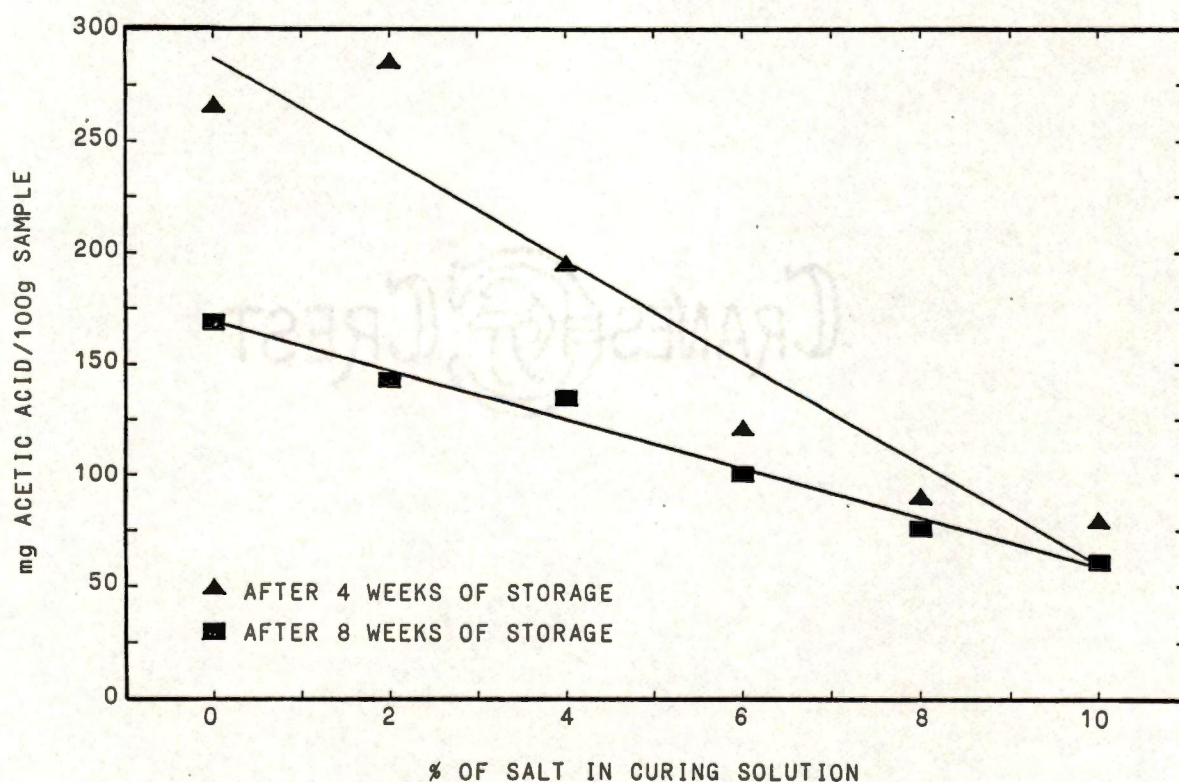


Figure 5. Effect of salt level and storage time on acetic acid in cured and dried beef cubes.

Table 4. Means and standard deviations of propionic acid in cured and dried beef cubes at different salt levels.

Salt level	mg propionic acid/100 g sample
0%	6.88 $\pm$ 11.46
2%	5.50 $\pm$ 6.64
4%	2.61 $\pm$ 2.31
6%	1.88 $\pm$ 0.71
8%	1.64 $\pm$ 0.54
10%	1.60 $\pm$ 0.80

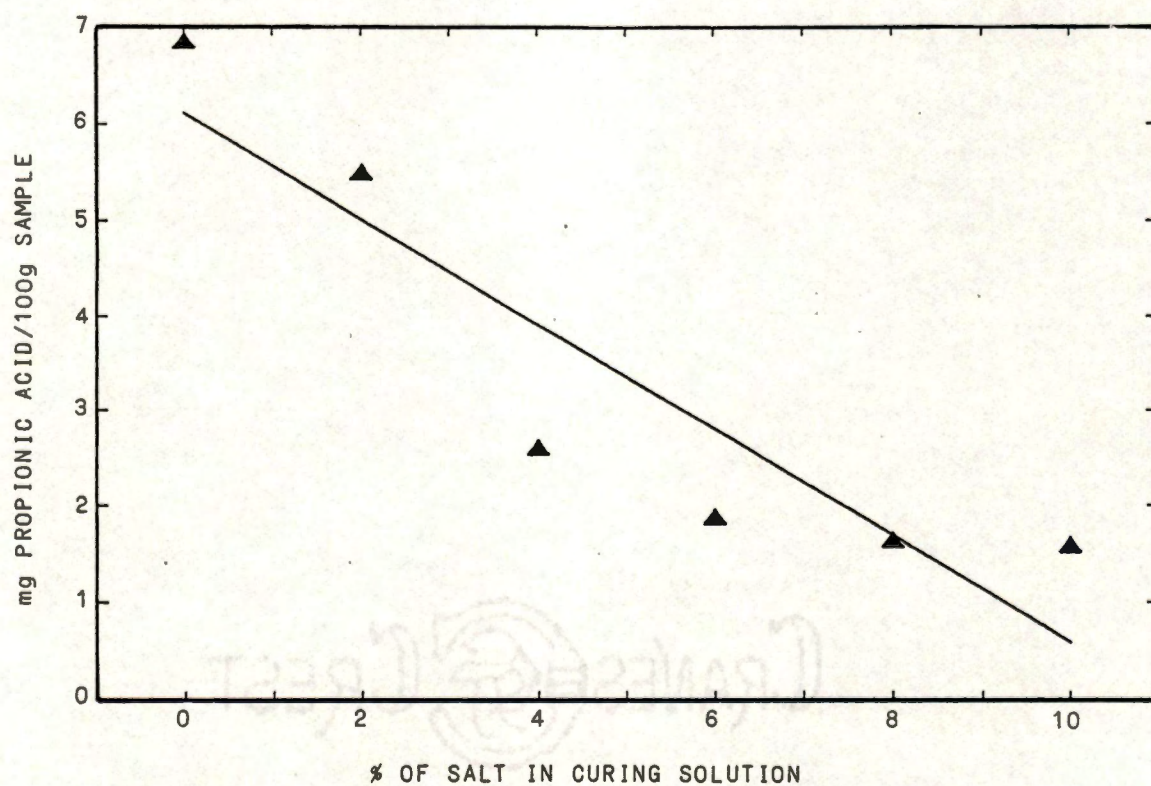


Figure 6. Effect of salt on propionic acid in cured and dried beef cubes.

Table 5. Means and standard deviations of butyric acid in cured and dried beef cubes at different levels of salt and storage period.

Salt level	After 4 weeks of storage			After 8 weeks of storage		
	 mg acid/ 100 g sample.					
0%	115.11	±	130.47	73.02	±	82.95
2%	105.41	±	108.35	57.61	±	58.85
4%	59.33	±	71.55	46.97	±	50.01
6%	17.35	±	20.42	16.54	±	19.87
8%	4.87	±	5.86	5.35	±	7.71
10%	5.66	±	14.30	3.70	±	7.86

salt levels, and the curves obtained (Figure 7) illustrate the trend of salt effect on butyric acid. These curves show that during the curing process, increased levels of salt in the solution decreased the production of butyric acid in the meat medium. Products stored for 8 weeks had lower values of butyric acid than products stored for 4 weeks at room temperature, at all levels of salt.

As for the decreased amounts of the volatile fatty acids observed with increased salt levels, one explanation could be that salt controlled microbial spoilage which could have enhanced the production of these acids. This view is in agreement with the report of Stumbo et al., (1945) that

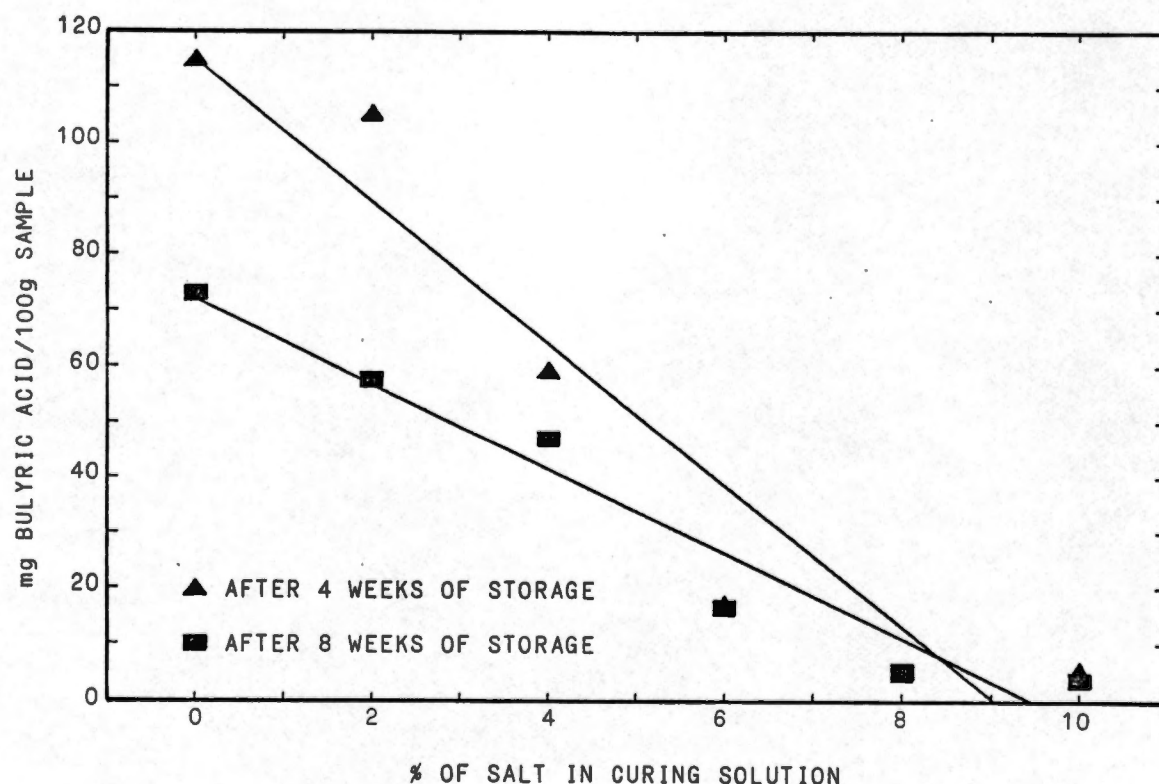


Figure 7. Effect of salt level and storage time on butyric acid in cured and dried beef cubes.

salt was more important than sodium nitrite in preventing the growth of the spores of putrefactive anaerobic spoilage bacteria. The decrease observed in acetic and butyric acids with storage time might be explained by the volatility of these acids during storage at room temperature in unsealed polyethylene bags.

The ratio of the observed butyric to the observed acetic acid was also examined with relation to varying salt levels. A plot of this ratio against the salt levels (Figure 8) showed an inverse relationship between the ratio and salt levels. Specifically butyric/acetic acid ratio decreased with increased salt level. This relationship was not surprising since increased salt levels had decreasing effect on butyric acid too.

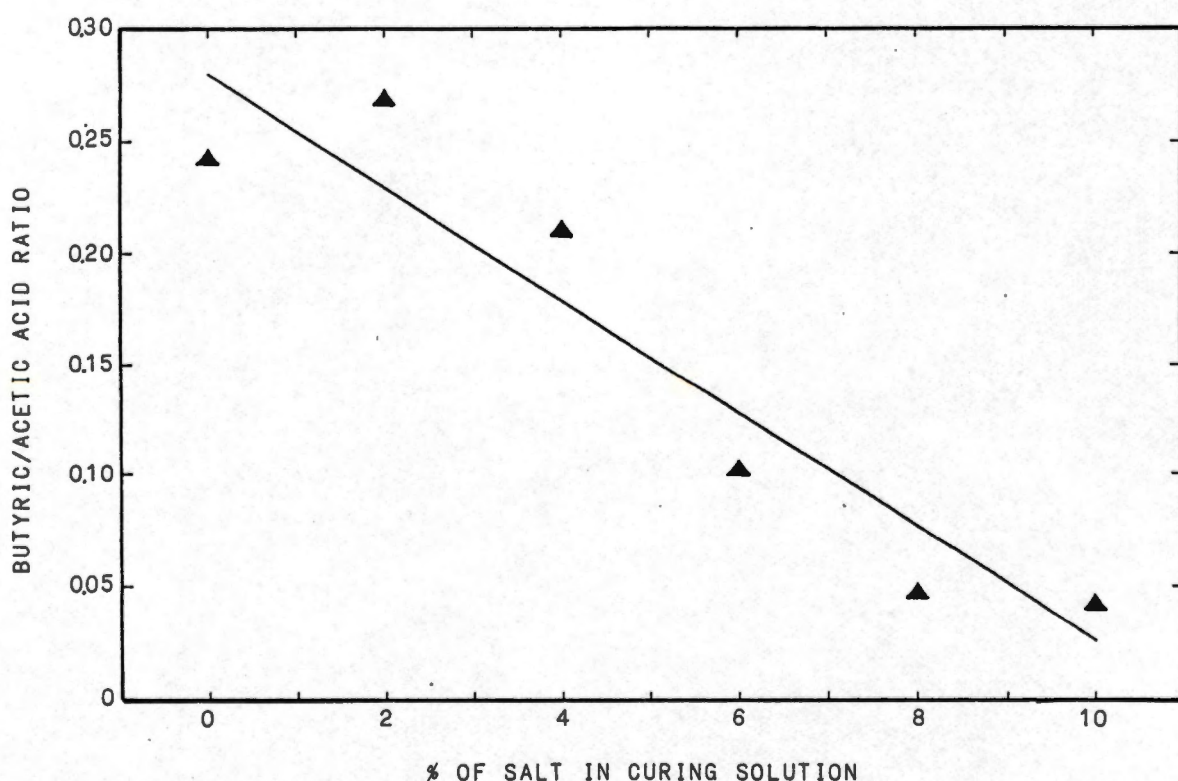


Figure 8. Effect of salt level on the butyric/acetic acid ratio in cured and dried beef cubes.

IV. THE EFFECT OF SALT LEVEL ON THE THIOBARBITURIC ACID (TBA) NUMBER OF CURED AND DRIED BEEF CUBES

Salt significantly ($p < 0.001$) affected the TBA number of cured and dried beef cubes (Appendix 10). The means and standard deviations of TBA numbers for the product at various salt levels studied are shown in Table 6. A plot of the observed TBA numbers against the salt levels are shown in Figure 9. The curve of this plot together with the observed means indicate that salt added to the curing solution reduced the TBA number of the product. This implies that salt addition to the curing solution controlled rancidity development, or otherwise oxidation of lipid in the product. Though the curve suggested a fourth power relationship between the observed TBA number and the added salt level, it might be assumed that when experimental errors and sample variations are considered, the curve simply indicated that only about 2% salt was

Table 6. Means and standard deviations of TBA numbers of cured and dried beef cubes at various salt levels.

Salt level	TBA Number
0%	4.61 $\pm$ 3.73
2%	0.27 $\pm$ 0.18
4%	0.24 $\pm$ 0.24
6%	0.37 $\pm$ 0.37
8%	0.34 $\pm$ 0.20
10%	0.39 $\pm$ 0.22

necessary to control rancidity in the product, and higher levels of salt added to the curing solution did not enhance or retard rancidity more than already achieved by 2% level.

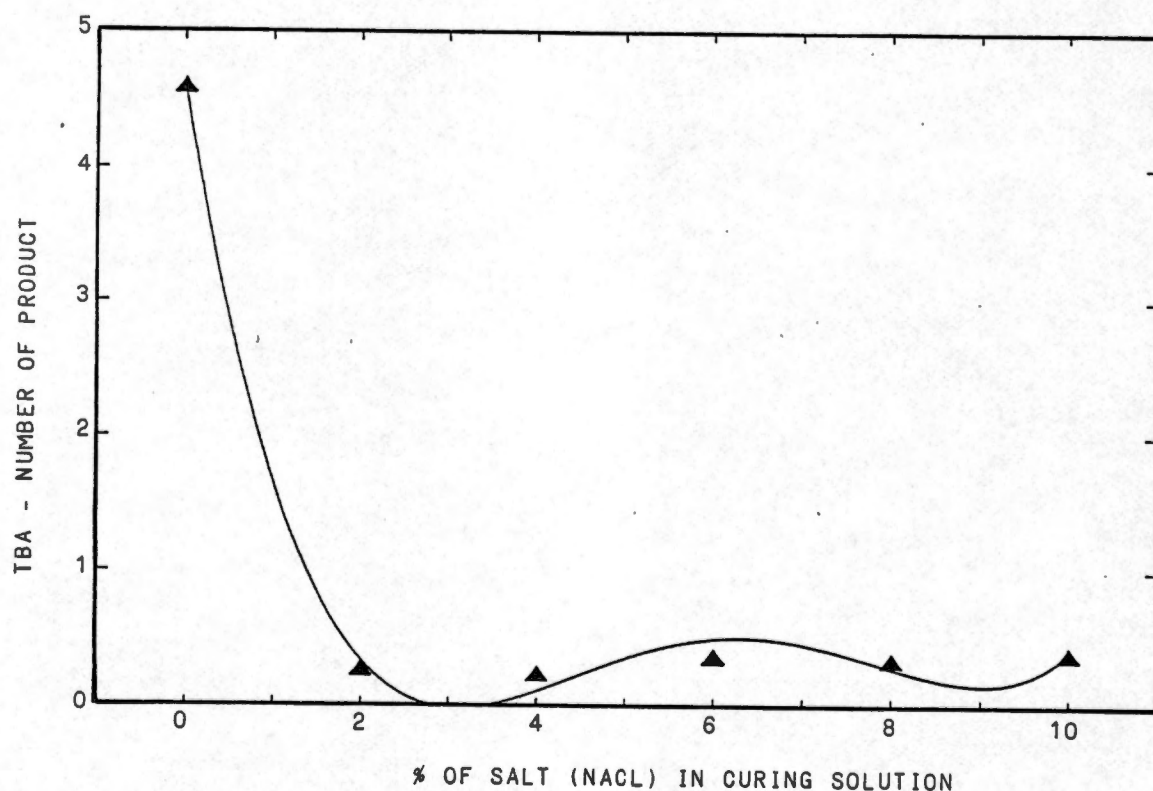


Figure 9. The effect of salt level on TBA number of cured and dried beef cubes.

V. THE EFFECT OF SALT LEVEL AND STORAGE TIME ON THE WATER (MOISTURE) CONTENT OF CURED AND DRIED BEEF CUBES

The water content of cured and dried beef cubes packaged in polyethylene bags was significantly affected by salt ($p < 0.01$) and storage time ($p < 0.05$), as indicated by the analysis of variance (Appendix 10).

These effects are illustrated on the table of mean water values (Table 7) and the plots of these values against the levels of salt (Figure 10). The data and curves show that the water content of the cured and dried beef cubes increased linearly with increased salt levels in the curing solution. This result agreed with the report of Wierbicki et al., (1954) that injection of beef muscle with solutions of salt, increased the meat's water-holding capacity. Samples stored for 8 weeks at room temperature showed lower values of water content at all salt levels. This suggested that the samples were losing moisture to the environment instead of absorbing moisture. If such an assumption is true then the product should become drier with storage time and less susceptible to mold growth.

Table 7. Means and standard deviations of the percentage water content of cured and dried beef cubes at different levels of salt and storage time.

Salt level	After 4 weeks of storage			After 8 weeks of storage		
	 %					
0%	20.18	±	6.07	19.82	±	5.98
2%	23.05	±	4.24	21.89	±	2.72
4%	23.40	±	2.74	23.35	±	3.42
6%	26.67	±	1.76	25.46	±	1.90
8%	26.76	±	1.32	26.12	±	1.32
10%	27.72	±	1.73	27.36	±	1.14

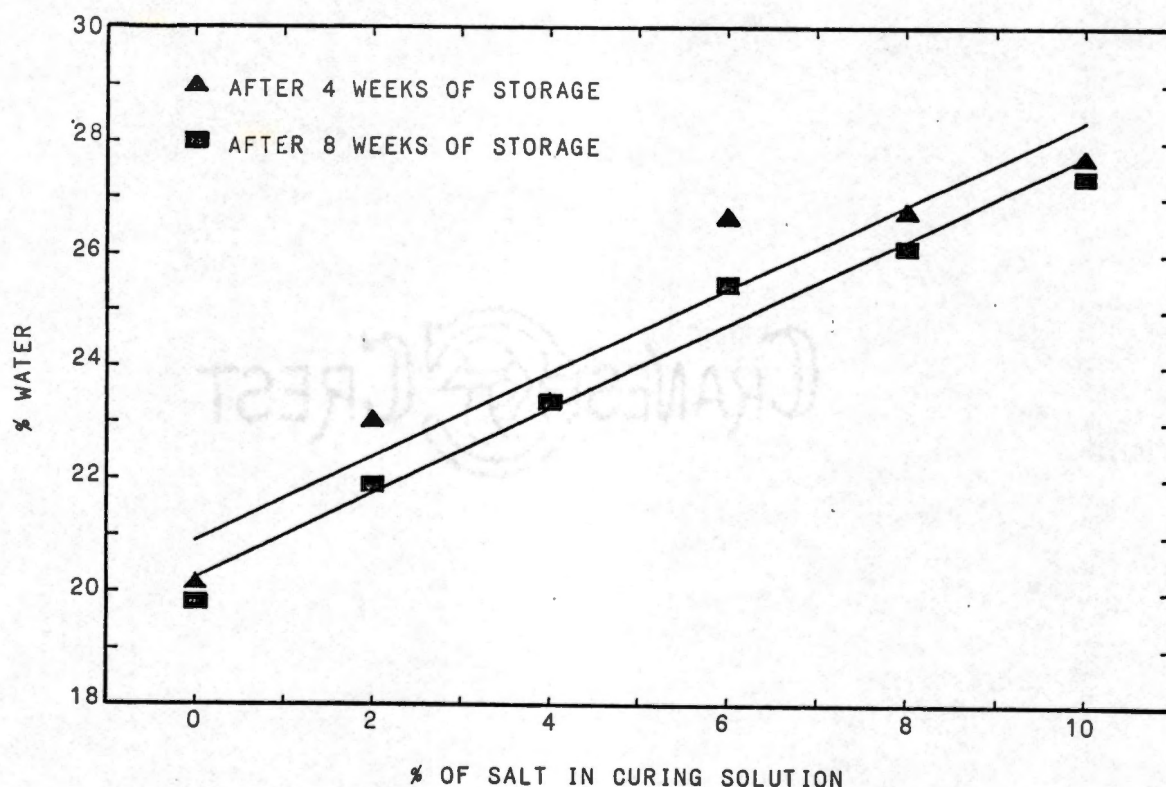


Figure 10. Effect of salt level and storage time on the water content of cured and dried beef cubes.

VI. THE EFFECT OF PAPAYA PULP ADDED TO CURING SOLUTIONS, AND THE STORAGE TIME ON THE pH AND TITRATABLE ACIDITY OF CURED AND DRIED BEEF SYSTEMS

Papaya pulp slurry added to the curing solution significantly affected the pH values of the curing solution before the curing process ($p < 0.001$), and after 48 hours of the curing process ($p < 0.01$). The pH values of the cured and dried beef products were also affected by papaya ($p < 0.001$) and storage time ($p < 0.05$) as observed in the analysis of variance (Appendix 10). The means and standard deviations of the observed pH values for the various solutions are shown in Table 8.

Table 8. Means and standard deviations of pH values of curing solutions before and after 48 hours of curing at various papaya levels.

Papaya levels	Before Curing	After 48 hours of Curing
0%	7.09 $\pm$ 0.17	5.34 $\pm$ 0.20
5%	6.41 $\pm$ 0.41	4.90 $\pm$ 0.27
10%	5.82 $\pm$ 0.41	4.82 $\pm$ 0.26
15%	5.44 $\pm$ 0.37	4.75 $\pm$ 0.24
20%	5.23 $\pm$ 0.31	4.71 $\pm$ 0.21
25%	5.05 $\pm$ 0.23	4.67 $\pm$ 0.19

The plot of these values against the level of papaya added is shown in Figure 11. These results show clearly that added papaya lowered the pH of the curing solutions before curing and after 48 hours of curing. The slopes of the curves indicated that the rate of pH decrease with added papaya was higher in the solution before the curing process than in the solution after 48 hours of curing. The curve obtained after 48 hours of curing suggests that the necessary level of papaya required to keep the pH of the solution below 5.0 after 48 hours of curing was between 5 and 10%. Since the curve for pH after 48 hours of curing is below that obtained before the curing process at all curing levels, one might assume that some acid producing reactions especially fermentation had occurred in the meat to bring down the initial pH at all levels of papaya. Where papaya was present, fermentation of both the meat and the sugar in the papaya could occur to yield acids.

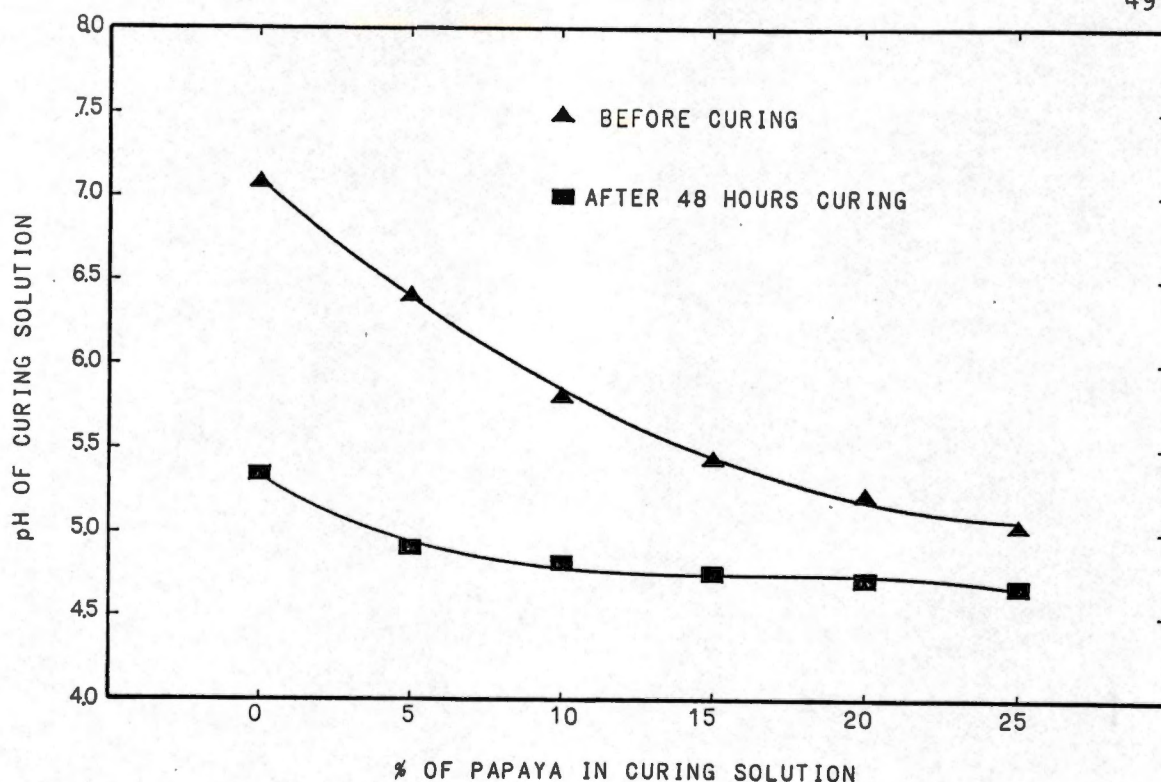


Figure 11. Effect of papaya on the pH of curing solution before and after curing.

The means and standard deviations of the pH values of the cured and dried beef product are shown in Table 9, and the curves obtained by plotting these pH values against the papaya levels are shown on Figure 12. These values together with the curves of Figure 12 showed that addition of papaya slurry in the curing solution lowered the pH of the finished product, the higher the level of papaya added, the lower the pH of the finished product--within the range of papaya level used in this study. Samples stored at room temperature for 8 weeks had higher pH values than samples stored for 4 weeks, at all papaya levels. Since the quantity of volatile fatty acids in the product decreased with storage time,

Table 9. Means and standard deviations of the pH values of cured and dried beef cubes at various levels of papaya and storage time.

Papaya level	After 4 weeks storage	After 8 weeks storage
0%	5.52 $\pm$ 0.10	5.54 $\pm$ 0.25
5%	5.27 $\pm$ 0.22	5.33 $\pm$ 0.39
10%	5.17 $\pm$ 0.28	5.23 $\pm$ 0.37
15%	5.17 $\pm$ 0.31	5.31 $\pm$ 0.60
20%	5.08 $\pm$ 0.32	5.10 $\pm$ 0.34
25%	5.01 $\pm$ 0.27	5.12 $\pm$ 0.46

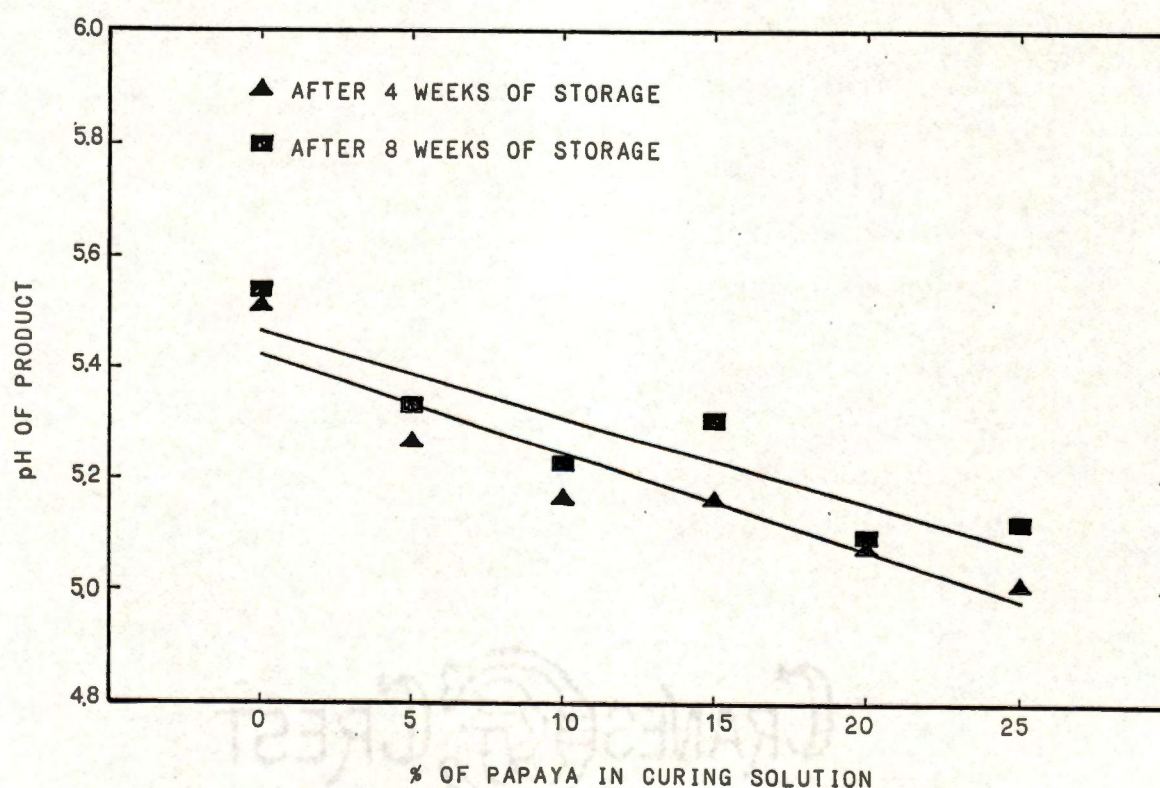


Figure 12. Effect of papaya and storage time on the pH of cured and dried beef cubes.

one would expect the pH of the product to increase with storage after all lower quantity of acids, volatile ones inclusive would mean higher pH value.

The titratable acidity (TA) of the product was affected by papaya and storage time, both at $p < 0.001$ level of significance (Appendix 10). The trend of these effects are illustrated by the table of means (Table 10) and the curves obtained after plotting the observed TA-values against the papaya levels (Figure 13). The results show that titratable acidity of the finished product has direct linear relationship with the level of papaya slurry in the curing solution. That meant that increasing the level of papaya in the curing solution increased the titratable acidity of the cured and dried beef cubes. This finding was not surprising since papaya as a fruit would increase the acidity of a medium even if it was fresh, and when its sugar content is fermented by

Table 10. Means and standard deviations of the titratable acidity (TA) of cured and dried beef cubes at various levels of papaya and storage time.

Papaya levels	After 4 weeks storage	After 8 weeks storage
0%	27.04 $\pm$ 2.96	29.89 $\pm$ 4.57
5%	31.84 $\pm$ 5.37	35.72 $\pm$ 5.18
10%	35.71 $\pm$ 4.77	38.86 $\pm$ 5.72
15%	37.29 $\pm$ 7.75	40.71 $\pm$ 8.39
20%	40.27 $\pm$ 3.01	40.77 $\pm$ 4.60
25%	40.68 $\pm$ 4.27	43.91 $\pm$ 5.30

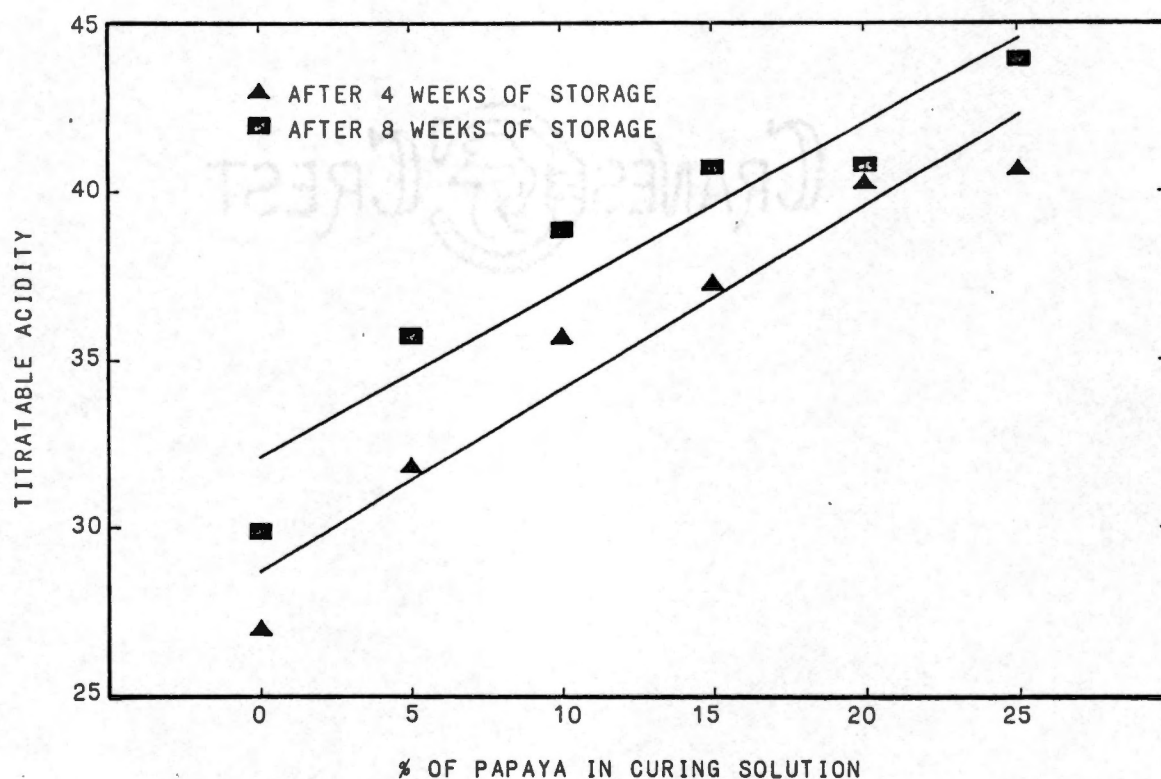


Figure 13. Effect of papaya and storage time on the titratable acidity of cured and dried beef cubes.

the microbes during curing, the containing medium would still be more acidic. The curves also indicated that titratable acidity increased with storage time at all papaya levels examined. This storage effect is consistent with that shown in Figure 3 (page 36), which illustrates the salt effect on titratable acidity of samples stored 4 and 8 weeks.

VII. THE EFFECT OF PAPAYA PULP ADDED TO CURING SOLUTION ON THE VOLATILE FATTY ACIDS OF CURED AND DRIED BEEF CUBES

Among the three volatile acids identified in cured and dried beef cubes, only propionic acid was significantly ($p < 0.001$) affected by the addition of papaya (Appendix 10). The effect was observed in the means

of this acid (Table 11) and is further illustrated by the plot of its mean values against papaya levels (Figure 14). The curve of this plot indicated a cubic relationship between the added papaya and the resulting amount of propionic acid in the finished product. When experimental errors and sample variations are considered, these results simply imply that only between 5 to 10% papaya was required to lower the level of propionic acid to about 2 mg/100 g sample of the finished product.

Table 11. Means and standard deviation of propionic acid in cured and dried beef cubes as affected by papaya levels.

Papaya levels	mg propionic acid/100 g sample
0%	7.40 $\pm$ 11.14
5%	3.03 $\pm$ 3.31
10%	2.04 $\pm$ 1.35
15%	3.09 $\pm$ 6.16
20%	2.74 $\pm$ 3.33
25%	1.82 $\pm$ 1.15

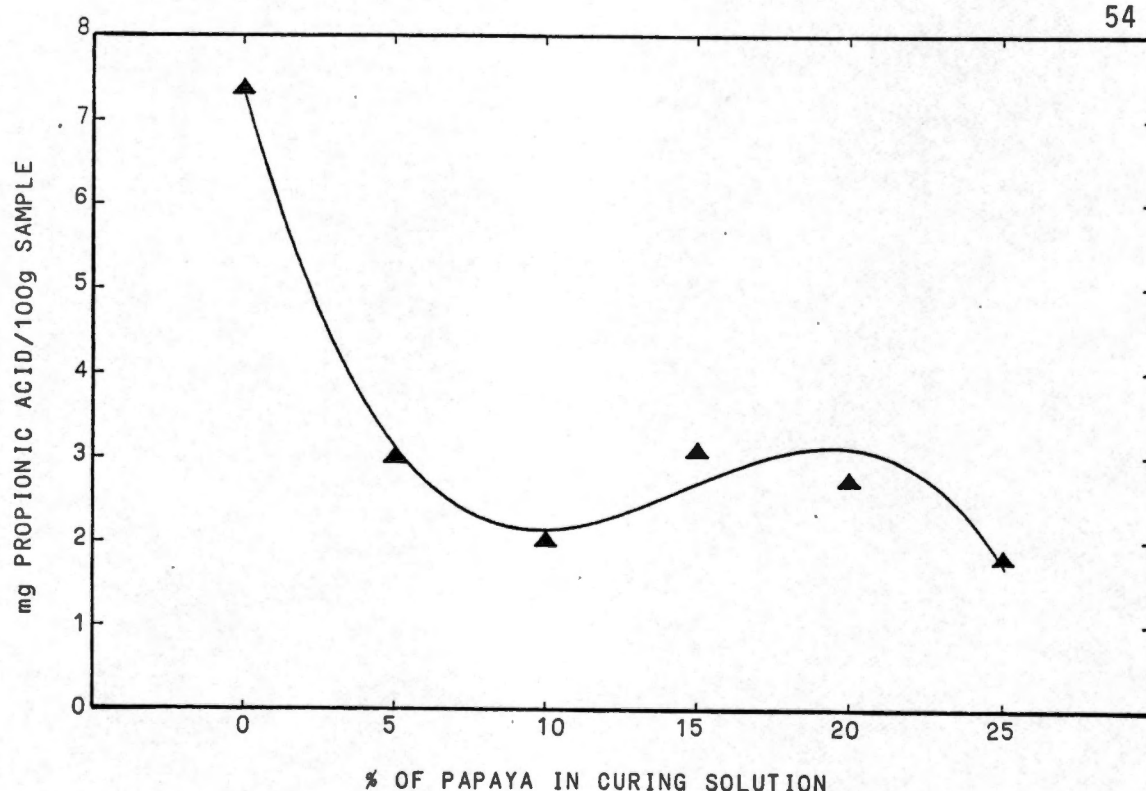


Figure 14. Effect of papaya on propionic acid in cured and dried beef cubes.

VIII. REHYDRATION OF CURED AND DRIED BEEF CUBES DURING COOKING

The means and standard deviations of the percentage of water reabsorbed by 9.91 ± 1.35 g samples of the dried meat product during boiling are shown in Table 12. A plot of these means against the period of boiling is shown in Figure 15. The curve obtained indicates that the product reabsorbed water rapidly during the first thirty minutes of boiling, achieving about 8% water of reabsorption. The rate of reabsorption decreased after 30 minutes but reabsorption continued up to about 75 minutes of boiling time when about 10.5% reabsorption value was reached. The curve leveled off and approached a constant value of about 11% after seventy five minutes of boiling. This curve suggested that at least

Table 12. Means and standard deviations of percentage water reabsorbed by the product during cooking for various time periods.

Time of boiling (in minutes)	Mean % of water reabsorbed
15	3.25 $\pm$ 0.80
30	7.94 $\pm$ 3.25
45	8.24 $\pm$ 4.68
60	10.42 $\pm$ 1.26
75	10.76 $\pm$ 2.33
90	11.14 $\pm$ 3.52
105	10.95 $\pm$ 3.41
120	11.12 $\pm$ 1.45

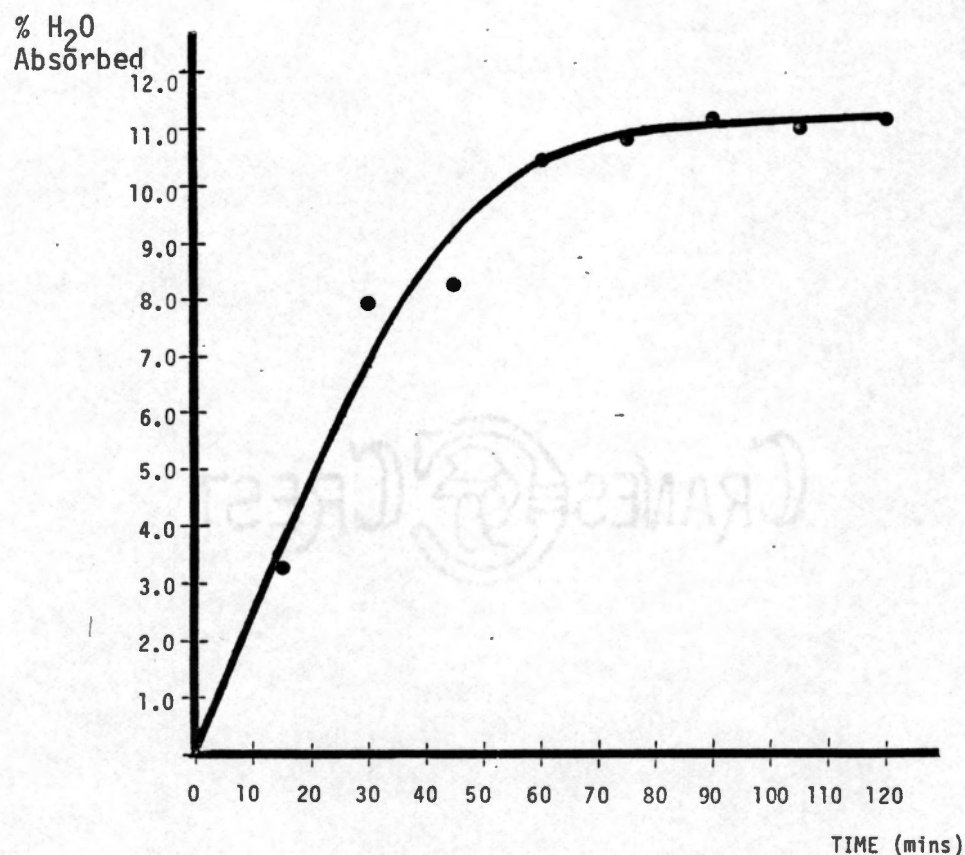


Figure 15. Rehydration of cured and dried beef cubes during cooking.

50 minutes of cooking was necessary for the reconstitution of the product, with respect to water, and that practically it was not necessary to boil the product for more than 60 minutes if the objective was only to rehydrate it. It may be stated that the reabsorbed water was an addition to the moisture content of 27.17 ± 0.16 possessed by the finished product (Appendix 11).

IX. CONSUMER ACCEPTANCE OF CURED AND DRIED BEEF CUBES

The analysis of variance of the consumer taste panel scores and prices for the dried beef cubes is shown in Table 13. This analysis

Table 13. Analysis of variance of consumer taste panel scores and prices for dried "beef cubes."

Consumers' Continent	Variable	Source	df	Mean Square	Error Mean Square	R-Square
<u>Plain boiled product</u>						
Africa	Score	Treatment ^a	1	13.225*	2.257	0.134
North America	Score	Treatment ^a	1	189.102***	1.801	0.550
Africa	Price	Treatment ^a	1	0.507	0.673	0.023
North America	Price	Treatment ^a	1	27.276***	0.502	0.420
<u>Product served in soup</u>						
Africa	Score	Treatment ^a	1	28.900***	1.924	0.283
North America	Score	Treatment ^a	1	31.920***	1.791	0.172

^aTreated and control product

*p < 0.05

***p < 0.001

indicated a significant difference in the acceptability scores for the treated and control products served plain-boiled, as rated by consumers from African ($p < 0.05$) and North American ($p < 0.001$) continents. These differences are observed in the means and standard deviations of these parameters shown in Table 14. The Africans had an average score of 6.60 ± 1.27 , equivalent to a moderate likeness for the treated plain-boiled product, and an average score of 5.45 ± 1.70 , equivalent to a slight likeness for the control plain-boiled product. The North Americans had an average score of 5.98 ± 1.05 , equivalent to slight likeness for the treated product plain-boiled, and an average score of 3.05 ± 1.58 , equivalent to moderate dislikeness for the control product plain-boiled. When the products were served in soup, the African members gave an average score of 7.35 ± 0.88 , interpreted as "liked very much" to the treated product, and an average score of 5.65 ± 1.76 , interpreted as "liked slightly" to the control product. With regards to their average scores the North American members of the consumer taste panel liked the treated product in soup moderately (score of 6.09 ± 1.34) and they disliked the control product in soup slightly (score of 4.89 ± 1.51). These results showed that members from both continents preferred the treated product to the control product. Even so, for each product the panel members preferred it served in soup rather than served plain-boiled. This is in agreement with the finding of the U.S. Department of Agriculture (1944) that palatability scores of dehydrated meat increased with increased addition of vegetable and seasonings in stews. The treated product was described by members of the panel as having good flavor, good odor, smokey flavor, good texture, and being a bit salty, tender, good for camping

Table 14. Treatment means and standard deviations of consumer taste panel scores and prices for dried beef cubes.

Consumer's Continent of origin	Product tested	Score ^a	Price ^b offered by consumers for pound of product
Africa ^c	Treated Product plain boiled and served	6.60 $\pm$ 1.27	2.24 $\pm$ 0.84
Africa ^c	Control Product plain boiled and served	5.45 $\pm$ 1.70	2.00 $\pm$ 0.80
Africa ^c	Treated Product served in soup	7.35 $\pm$ 0.88	
Africa ^c	Control Product served in soup	5.65 $\pm$ 1.76	
North America ^c	Treated Product plain boiled and served	5.98 $\pm$ 1.05	1.72 $\pm$ 0.70
North America ^c	Control Product plain boiled and served	3.05 $\pm$ 1.58	0.52 $\pm$ 0.71
North America ^c	Treated Product served in soup	6.09 $\pm$ 1.34	
North America ^c	Control Product served in soup	4.89 $\pm$ 1.51	

^aScore of 8=like extremely, 7=like very much, 6=like moderately, 5=like slightly, 4=dislike slightly, 3=dislike moderately, 2=dislike very much, 1=dislike extremely.

^bMean price the consumers are willing to pay given that the price of fresh beef is \$2.00 per pound at supermarket.

^cTwenty Africans and 44 North Americans took part in the evaluation.

and country ham-like. On the other hand, the control product was described by members as being tough to chew, stringy, leather like, dry, bland and having poor taste and off flavor.

There was no significant difference between the prices the African consumer taste panel members were willing to pay for both treated and control products. However, there was significant difference ($p < 0.001$) between the prices the North American members were willing to pay for the products. Specifically, while the Africans were offering an average price of 2.24 ± 0.84 dollars for a pound weight of the treated product and 2.00 ± 0.80 dollars for the control product (given that the price of fresh beef at supermarket was 2.00 dollars per pound), the North American members were offering an average of 1.72 ± 0.70 dollars for the treated product and 0.52 ± 0.71 dollars for the control product. It was not surprising that for each product, the average African members' score was higher than that of the North American members; nor was it surprising that there was no significant difference between the average prices the Africans were willing to pay for both treated and control products. This could be explained by the old adage that "the old is better". After all, the control product was prepared in the "old" way known to the Africans and it had the old taste and texture known to them. Though in this study, the "old" (control) was still good for them, but the "new" (treated) was rated better if the average scores were taken for granted.

X. CONCLUSION

This study is concluded with the recommendation that dried beef products, more acceptable than those presently available in Nigeria, with regards to tenderness, flavor and appearance can be obtained by curing fresh cut beef in solutions of about 8 to 10% salt (NaCl) and 10 to 20% papaya slurry (based on the weight of water), at room temperature for 48 hours and drying at 48.9°C for 45 hours. The choice of curing solution recommended is based on experimental observations shown in Table 15. It was observed that the putrid odor disappeared with the addition of papaya in solutions of 6% salt or higher and weak fermentative odor and a bleaching of the samples ceased with addition of papaya in solutions of 8% salt or higher. The volatile fatty acid content, TBA numbers and titratable acidity of the finished products were also considered in relation to their values in fresh beef (Appendix 11). This was done on the hypothesis that any product high in butyric acid value would be unacceptable in taste since butyric acid has very objectionable odor, and that higher TBA number would result in higher rancidity taste while excessive value of acetic acid content would result in an objectionable sour taste. The choice for the consumer taste panel was influenced by the finding of Castro-Espinoza (1982) that the treatment containing 10% NaCl with 10% papaya had an acceptable microflora. Though the product was treated in 10% salt solution, the level of salt in the dried product was 8.03% and even so, it had 2.30% salt when eaten plain boiled and 1.78% when eaten in soup (based on weight of product). These salt values are in line with those found in most other salt cured meat products.

Table 15. Observations of the cured and dried beef cubes during their production.

Papaya levels	Salt levels					
	0%	2%	4%	6%	8%	10%
0%	b P t	b P t	P t	P	S	S bleached samples
5%	b P t	b P t	b P t	t		
10%	b P t	b P t	b P t	b S		
15%	b P t	b P t	b P t	S t		
20%	b P t	b P t	b P t	b S		
25%	b P t	b P t	b P t	b S	b	

b=bulged containers (gas produced); P=putrid smell; S=weak fermentative smell; t=surface mold growth during storage.

CHAPTER V

SUMMARY

In this study the top and bottom rounds of U.S. Commercial grade beef carcasses were cut into pieces of about 3 X 4 X 5 cm after trimming of external and seam fat layers. The resulting cubes had about 4% fat content. About two pounds sample of these cuts were cured in each of 36 different salt-papaya brines prepared by varying the amount of salt in the solution from 0% to 10% in increments of 2 and the amount of papaya slurry from 0% to 25% in increments of 5. Samples were cured in covered food-grade plastic containers at $22.7^{\circ}\text{C} \pm 1.4$ for 48 hours. Cured samples were rinsed with tap water and dried at an isothermal smoke house temperature of 48.9°C . Wood smoke was applied to the product for one hour after a 30 minutes drying period. The drying operation was carried out for 45 hours to achieve a water activity of about 0.50 in the samples treated in plain tap water without salt or papaya. Dried samples were cooled and packaged in polyethylene bags. These packages were stored for 8 weeks at room temperature. Samples were taken from each of the 36 treatments (after 4 and 8 weeks of storage) and analyzed for volatile fatty acid content, moisture content, pH, titratable acidity and thiobarbituric acid number (rancidity indicator). The means and analysis of variance of these parameters were computed to determine the effects of salt levels, papaya levels and storage time. The chemical results and the microflora information on these samples supplied by Castro-Espinoza (1982) were utilized in choosing the best treatment level for an acceptable consumer product.

There isn't such thing

The results indicated that the salt added to the curing solution decreased the pH of the initial curing solution however after 48 hours of curing, solutions containing 8 to 10% salt had slightly higher pH values.

In the finished product, salt decreased the average amounts of acetic ($p < .05$), propionic ($p < 0.001$), and butyric ($p < 0.05$) acids. The greater the level of salt added, the lower the amount of the acids observed. The added salt also decreased the titratable acidity ($p < 0.001$) and slowed rancidity development ($p < 0.001$) in the finished product. Within the range of salt levels studied, the higher the amount of salt added, the lower the titratable acidity values observed. With regards to the TBA-number (rancidity indicator), it seemed that only about 2% of salt in the solution was needed to lower the TBA number below 0.50. Salt increased the mean moisture content ($p < 0.01$) of the product and the higher the level of salt added, the greater the moisture content of the product.

The papaya slurry added to the curing solution decreased the pH of the curing solution ($p < 0.001$). The pH curve tended to level off beyond 20% papaya in the solution, suggesting that higher level of papaya was not necessary. The pH values of the finished products were also decreased ($p < 0.01$) by the added papaya, the higher the level of papaya added to the curing solution the lower was the observed pH values of the products within the range of papaya levels studied. The result showed that the papaya slurry added decreased the mean amount of propionic acid ($p < 0.001$) in the finished product and that only about 5% papaya was needed in the curing solution to keep the amount of propionic acid below 3 mg/100 g sample of product. The added papaya expectedly increased the

titratable acidity ($p < 0.001$) of the product. Within the range of papaya levels studied, the higher the level of papaya added the greater the titratable acidity of the product obtained. Samples stored for 8 weeks had higher values of titratable acidity and lower moisture contents at all levels of salt studied. The mean amount of acetic and butyric acids decreased ($p < 0.001$) with increased storage period.

On the sensory perceptions, all samples cured in solutions of 8 or more percentage of salt, with 5 or more percentage of papaya slurry had a normal fresh raw meat smell. Samples cured in the solution containing 10% salt and 10% papaya were chosen for sensory evaluation on the points that they had no putrid smell during curing, they showed no surface mold during storage, they had relative low values of individual volatile fatty acids, they had low TBA number and were found to have acceptable microflora by Castro-Espinoza (1982).

Both the African and North American members of the consumer taste panel preferred the chosen cured and dried samples to the uncured dried samples used as the control in this study. The consumer taste panel scored the cured and dried product higher ($p < 0.001$) than the control product in overall acceptability. Most members remarked that the cured and dried product was more tender, more flavorful and more pleasing in appearance than the control product. All panel members were willing to pay more for the cured and dried product than for the control, though the difference in prices was greater with the North American members than with the African members.

This study indicates that conditions can be created (low pH and high salt levels) at which meat can successfully be preserved without

refrigerated temperatures. The addition of papaya had a three fold effect. It lowered the initial pH of the brine, helped to prevent surface mold on the dried product and increased tenderness. This method could assist under-developed countries in preserving meat that would have longer shelf life and be more palatable. In addition solar energy can be utilized in the tropics for some stage of the drying operation thus minimizing cost of production.

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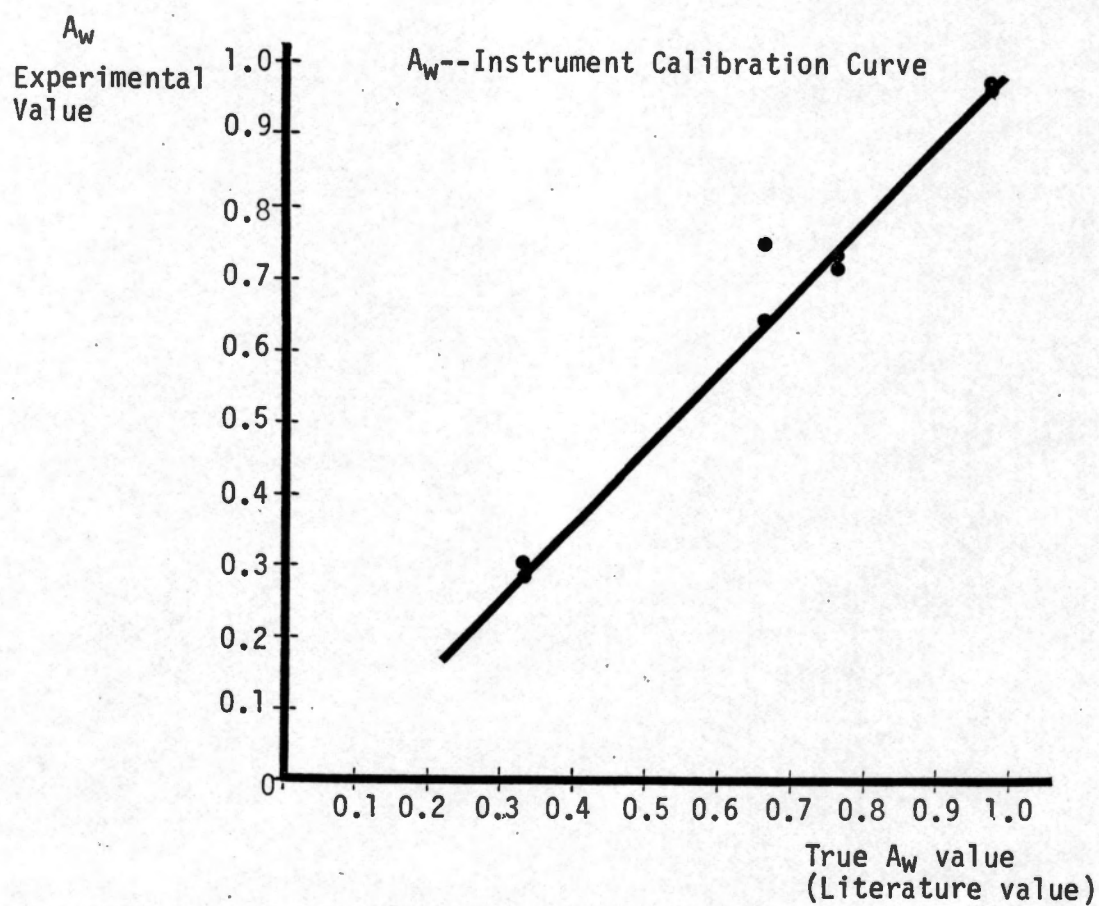
APPENDICES



APPENDIX 1

CALIBRATION CURVE FOR A_w DETERMINATION

<u>Saturated Salt Solutions</u>	<u>Mean calculated A_w value</u>	<u>Literature value (true value)</u>
K_2SO_4	0.97	0.97
NaCl	0.72	0.76
$NaNO_2$	0.70	0.66
$MgCl_2 \cdot 6H_2O$	0.29	0.33

Figure 16. Calibration curve for A_w determination.

APPENDIX 2

TOTAL LIPID IN PRODUCT SAMPLE

A fifteen gram sample of the powdered meat was extracted with chloroform-methanol solvents. The total volume (V_t) of chloroform layer was measured. Two 10 ml portions of this layer were dried in a weighed beaker in a vacuum oven at 70°C. These beakers were reweighed after drying and the weight of lipid (X g) was calculated. The average weight ($\bar{X}$ g) in 10 ml chloroform extract was found.

$$\text{Weight of lipid in 15 g sample} = \frac{(V_t \text{ ml}) (\bar{X} \text{ g})}{10 \text{ ml}}$$

Where V_t is the total volume of chloroform extract

$\bar{X}$ g is average weight of lipid in 10 ml portion

$$\% \text{ lipid in Sample} = \frac{(V_t \text{ ml}) (\bar{X} \text{ g})}{10 \text{ ml} (15 \text{ g})} \times 100$$

APPENDIX 3

RELATIVE RETENTION TIME OF VOLATILE FATTY ACIDS

Peak identification

The chromatograms of the samples and a standard solution of volatile fatty acids were obtained under the same conditions. The retention times of all components were recorded and the relative time of each component to that of internal standard was calculated. Identification of the fatty acids in samples was achieved by matching their retention times and relative retention times with those obtained for standard solution.

$$\text{Relative Retention time} = \frac{\text{Retention time of Component}}{\text{Retention time of internal standard}}$$

<u>Component</u>	<u>Retention time (min.)</u>	<u>Relative Retention Time</u>
Methyl heptyl ketone (internal standard)	4.30	
Acetic acid	5.36	1.25
Propionic acid	8.10	1.88
Butyric acid	12.43	2.89

APPENDIX 4

CORRECTION FACTOR FOR DISTILLATION LOSS OF VOLATILE FATTY ACIDS

Five milliequivalents in 150 ml solution of each volatile fatty acid identified in the sample were separately distilled in the constant volume distilling apparatus as the samples. Two hundred ml of distillate were collected for each acid and titrated with 0.10 N sodium hydroxide solution. The amount of each acid recovered was determined in milliequivalents (meq) and the percentage recovery calculated.

meq of acid = normality of NaOH X Volume of NaOH used.

$$\% \text{ recovery} = \frac{\text{amount recovered}}{\text{amount distilled}} \times 100 = \frac{\text{meq recovered} \times 100}{5 \text{ meq}}$$

$$\text{Correction factor} = \frac{100\%}{\% \text{ recovery}}$$

<u>Component</u>	<u>Calculated distillation correction factor</u>
Acetic acid	1.75
Propionic acid	1.24
Butyric acid	1.08

Correction factor due to volume of extract distilled.

Added to product sample during extraction:

Water	200 ml
20% phosphotungstic acid	40 ml
1 N sulfuric acid	<u>25 ml</u>
TOTAL	265 ml

Volume distilled = 150 ml

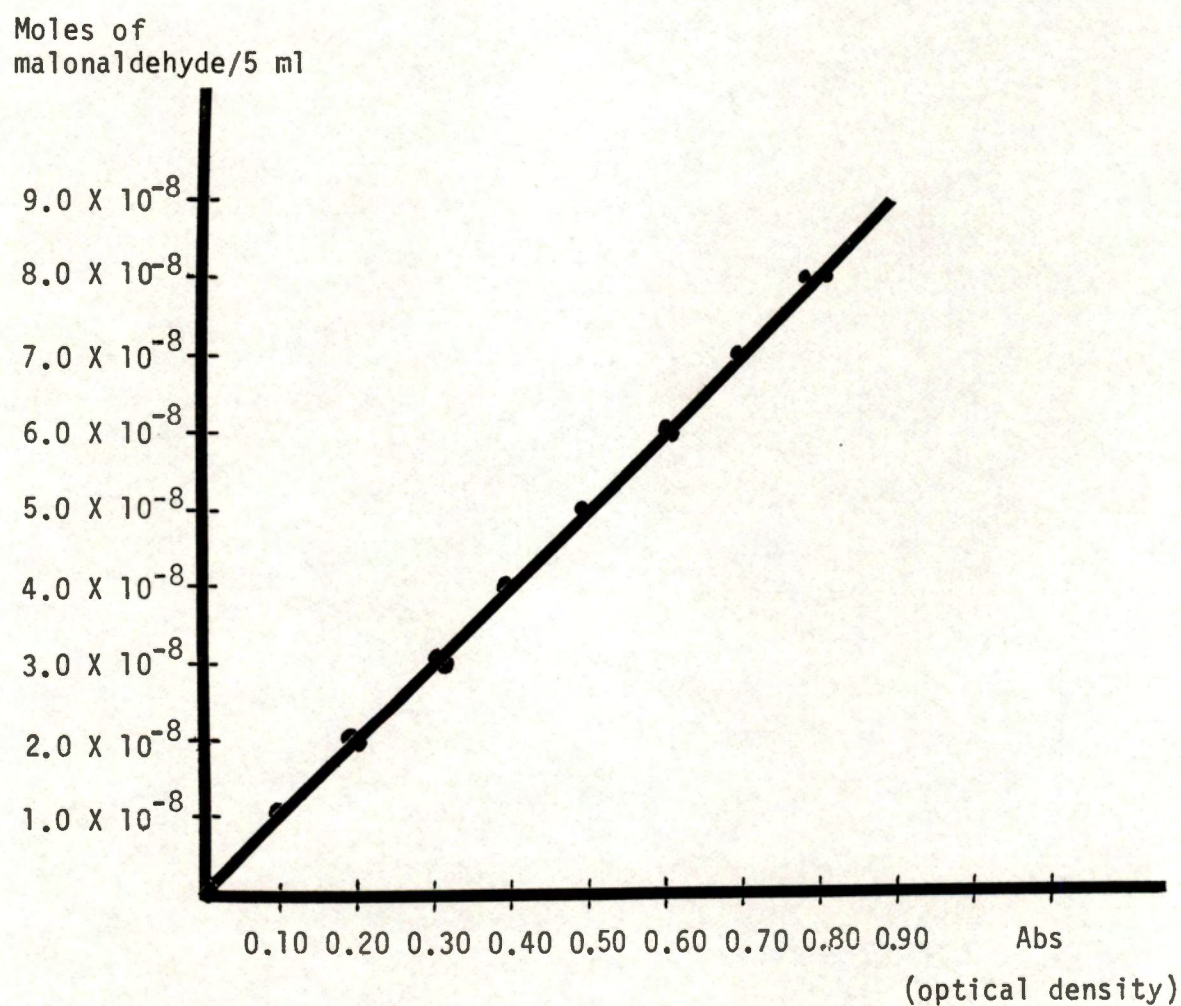
$$\text{Correction factor due to volume used} = \frac{265 \text{ ml}}{150 \text{ ml}} = 1.767$$

This factor is applied to each volatile fatty acid. To get the actual experimental value of any volatile fatty acid, the amount obtained by GLC is multiplied by 1.767 and by the distillation correction factor for that acid.



APPENDIX 5

STANDARD CALIBRATION CURVE FOR TBA ANALYSIS



$$\frac{\text{Conc in moles/5 ml distillate}}{\text{Optical density (Abs.)}} = 1.0 \times 10^{-7}$$

Figure 17. Standard calibration curve for TBA analysis.

APPENDIX 6

DETERMINING THE PERCENT RECOVERY OF MALONALDEHYDE

Five ml of a solution of 1, 1, 3, 3-tetraethoxypropane containing 5.0×10^{-7} mole of solute was pipeted into each of three Kjeldahl flasks. Ninety eight ml of distilled water and 2 ml of approximately 4 N hydrochloric acid solution were added. The contents were distilled until 50 ml of distillate were collected from each flask. TBA-reactions are carried out and absorbance values were obtained with 5 ml portions from each distillate. Using the absorbance values, the average mole of malonaldehyde in the 5 ml portions was obtained from the calibration curve of Appendix 5. The average value obtained was 2.704×10^{-8} mole of malonaldehyde in 5 ml of distillate.

$$\% \text{ Recovery} = \frac{2.704 \times 10^{-8} \text{ mole} \times 50 \text{ ml} / 5 \text{ ml}}{5.0 \times 10^{-7} \text{ mole}} \times 100$$

$$\% \text{ Recovery} = 54\%$$

Calculating the TBA number of samples

The TBA number (mg of malonaldehyde per 1000 g sample) of each sample was obtained by multiplying the absorbance value of that particular sample by a constant K.

$$K = a \times \text{mol. wt. of malonaldehyde} \times 100 \text{ mg/g} \times \frac{1000 \text{ g sample}}{\text{sample weight}}$$

$$\times \frac{50 \text{ ml}}{5 \text{ ml}} \times \frac{100\%}{54\%}$$

Where a = absorptivity or slope of the curve in Appendix 5.

In the analysis, 15 g samples were used and from the calibration curve of Appendix 5, the value of the first term in the equation,

$$a = 1.0 \times 10^{-7}$$

$$K = 1.0 \times 10^{-7} \times 72.065 \times \frac{10^7}{15} \times \frac{100}{54} = 8.8969 \quad 8.90$$

Then TBA number = Absorbance value $\times$ 8.90

APPENDIX 7

DETERMINING THE PERCENTAGE OF SALT (NaCl) IN PRODUCT

Ten ml of silver nitrate solution containing 4.996 miliequivalents (meq.) of solute were reacted with the salt (NaCl) contained in the 2 g sample analyzed. The excess silver nitrate unreacted was titrated with a standard (0.0998 N) NH_4SCN solution.

$$\text{meq of excess AgNO}_3 = V_1 \times N_1 = R_{\text{meq}}$$

Where V_1 is the volume of Standard NH_4SCN used.

N_1 is normality of NH_4SCN solution.

R_{meq} is the calculated excess AgNO_3 .

The amount of NaCl in 2 g sample = $4.996 \text{ meq} - R_{\text{meq}}$

$$\% \text{NaCl in sample} = (4.996 - R) \text{ meq} \times \frac{58.44 \text{ g NaCl}}{\text{eq wt.}} \times \frac{1 \text{ eq wt.}}{1000 \text{ meq.}} \times \frac{100\%}{\text{Wt. of sample}}$$

$$\% \text{NaCl} = (4.996 - R) \times 58.44 \times \frac{100}{2(1000)}$$

APPENDIX 8

DETERMINING THE PERCENTAGE OF PROTEIN IN PRODUCT

Powdered samples of the product (0.9 g) were digested and distilled with Kjeldahl apparatus. The distillates were collected into 4% acid to a total volume of 200 ml, and titrated with 0.1 N hydrochloric acid (HCl) solution. The miliequivalent (meq.) of nitrogen in the ammonia (NH_3) liberated was calculated from the volume and normality of the HCl used in titration.

$$\text{meq of Nitrogen (meq N)} = V_{\text{HCl}} \times N_{\text{HCl}}$$

Where V_{HCl} is the volume of HCl used in titration

N_{HCl} is the normality of HCl.

$$\% \text{ Protein} = \frac{(\text{meq N})}{\text{wt. of sample}} \times \frac{(0.014 \text{ g N})}{(\text{meq N})} \times \frac{6.25 \text{ g Protein}}{(\text{g N})} \times 100$$

APPENDIX 9

THE SENSORY EVALUATION SOUP

Composition:

228 g (8 oz.) of ground decorticated Nigerian melon seeds (Egwusi)

340 g (12 oz.) of Tomato paste

285 g (10 oz.) of chopped onion

570 g (20 oz.) of chopped spinach

630 g (200 pieces weighing 22 oz.) of dried meat

55 g (1/4 cup) of vegetable oil

2250 ml (10 cups) of water

8 g (1 tablespoon) of salt--added only in control product soup

Method of preparation:

The dried meat products were cut into pieces of the exact sizes tasted by the panel. These pieces of meat were boiled in 8 cups (1800 ml) of water for 30 minutes. The onion and tomato paste were fried in the vegetable oil for about two minutes. Then other ingredients including the meat and broth were added. Two more cups of water (450 ml) were added to the mixture and all ingredients cooked for 30 minutes. Eight to ten grams (1 tablespoon) of salt were added to the control product soup. At the end of 30 minutes cooking, the soup was ready to be served.

APPENDIX 10

ANALYSIS OF VARIANCE FOR THE DEPENDENT VARIABLES
OF CURED AND DRIED BEEF CUBES

Table 16. Analysis of variance for the dependent variables of cured and dried beef cubes.

Dependent Variable	Source	df	Mean Square	Error Mean Square	R Square
Acetic acid	Salt	5	101201.06*		
	Papaya	5	8311.17	46593.51 ^a	
	Storage	1	127172.06***	2304.73 ^b	0.97
Propionic Acid	Salt	5	123.68***		
	Papaya	5	100.84***	12.99 ^a	
	Storage	1	89.25	25.95 ^b	0.81
Butyric Acid	Salt	5	37325.06*		
	Papaya	5	5273.97	12184.60 ^a	
	Storage	1	10925.63***	758.44 ^b	0.96
Titratable Acidity	Salt	5	348.41***		
	Papaya	5	612.33***	19.97 ^a	
	Storage	1	289.71***	7.11 ^b	0.97
Thiobarbituric Acid-number	Salt	5	73.64***		
	Papaya	5	2.94	1.18 ^a	
	Storage	1	0.75	3.10 ^b	0.84
Percent moisture	Salt	5	196.18**		
	Papaya	5	2.97	26.13 ^a	
	Storage	1	14.40*	3.31 ^b	0.95
pH of cured and dried beef product	Salt	5	0.30		
	Papaya	5	0.68**	0.30 ^a	
	Storage	1	0.17	0.04 ^b	0.91
pH of Solution before curing	Salt	5	1.47*	0.16 ^a	
	Papaya	5	14.69***		1.00
pH of Solution after 48 hours of curing	Salt	5	0.38*	0.13 ^a	
	Papaya	5	1.47**		1.00

Table 16 (Continued)

Dependent Variable	Source	df	Mean Square	Error Mean Square	R Square
Propionic/Acetic acid ratio	Salt	5	0.003	0.002 ^a 0.00 ^b	0.76
	Papaya	5	0.002		
	Storage	1	0.000		
Butyric/Acetic acid ratio	Salt	5	0.24*	0.08 ^a 0.00 ^b	0.98
	Papaya	5	0.05		
	Storage	1	0.00		

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

^aError mean square for Salt and Papaya.

^bError mean square for Storage.

APPENDIX 11

COMPARATIVE ANALYSIS OF THE MEAT PRODUCTS AND RAW MATERIAL

Table 17. Comparative analysis of the meat products and raw material.

Parameters analyzed	Samples analyzed			
	Fresh papaya	Fresh meat	Uncured dried meat (control)	Cured and dried beef, salt 10%, papaya 10%
pH	4.89	5.58	5.90	5.49
Acetic acid	3.28	3.59	49.81	51.65
Propionic acid	0.00	0.00	1.33	0.62
Butyric acid	0.63	0.25	9.78	2.49
Propionic/Acetic Ratio	0.00	0.00	0.03	0.01
Butyric/Acetic Ratio	0.19	0.07	0.20	0.05
Protein (%)	---	22.93	74.62	53.51
TBA-number	---	0.15	2.10	0.29
Titratable Acidity	---	10.30	46.94	35.30 = .353 %
Fat (%)	---	3.86	10.16	5.49
Moisture	---	---	9.31	27.17
Salt (%)	---	---	---	8.03 ^a

^aThe cured and dried product has 2.30% salt when eaten plain-boiled, and 1.78% salt when eaten in soup.

APPENDIX 12

ANALYTICAL MODEL EQUATIONS FOR SOME PLOTTED CURVES

Figure 2. Effect of salt level (x) on pH of curing solution

pH of initial curing solution

$$Y = 6.13452381 - 0.05882143x$$

pH of curing solution after 48 hours of curing

$$Y = 4.83482143 - 0.04424107x + 0.00688244x^2$$

Figure 3. Effect of salt level (x) and storage time on titratable acidity of product

Titratable acidity of product after 4 weeks of storage

$$Y = 37.92190476 + 0.47821429x - 0.13199405x^2$$

Titratable acidity of product after 8 weeks of storage

$$Y = 40.77315476 + 0.77089583x - 0.17229911x^2$$

Figure 5. Effect of salt level (x) and storage time on acetic acid of product

mg acetic acid/100 g sample after 4 weeks of storage

$$Y = 287.23709921 - 22.78393095x$$

mg acetic acid/100 g sample after 8 weeks of storage

$$Y = 169.30716667 - 11.08500833x$$

Figure 6. Effect of salt level (x) on propionic acid of product

mg propionic acid/100 g sample

$$Y = 6.11624008 - 0.55292024x$$

Figure 7. Effect of salt level (x) and storage time on butyric acid of product.

mg butyric acid/100 g sample after 4 weeks of storage

$$Y = 114.91720238 - 12.72658214x$$

mg butyric acid/100 g sample after 8 weeks of storage

$$Y = 71.99367857 - 7.62606905x$$

Figure 8. Effect of salt level (x) on butyric/acetic acid ratio of product.

$$\begin{aligned} &\text{Butyric/Acetic Ratio} \\ &Y = 0.27974802 - 0.02534405x \end{aligned}$$

Figure 9. Effect of salt level (x) on the Thiobarbituric acid (TBA) number of product.

$$\begin{aligned} &\text{TBA-number of product} \\ &Y = 4.59762847 - 3.98111748x + 1.18139822x^2 - 0.13945479x^3 \\ &\quad + 0.00569331x^4 \end{aligned}$$

Figure 10. Effect of salt level (x) and storage time on water content of product.

$$\begin{aligned} &\text{Percent water of product after 4 weeks of storage} \\ &Y = 20.90750000 + 0.74458333x \end{aligned}$$

$$\begin{aligned} &\text{Percent water of product after 8 weeks of storage} \\ &Y = 20.25067460 + 0.74947619x \end{aligned}$$

Figure 11. Effect of papaya level (x) on pH of curing solution.

$$\begin{aligned} &\text{pH of curing solution before curing} \\ &Y = 7.09136905 - 0.15278452x - 0.00287500x^2 \end{aligned}$$

$$\begin{aligned} &\text{pH of curing solution after 48 hours of curing} \\ &Y = 5.32959656 - 0.10603946x + 0.00640608x^2 - 0.00012932x^3 \end{aligned}$$

Figure 12. Effect of papaya level (x) and storage time on pH of product.

$$\begin{aligned} &\text{pH of product after 4 weeks of storage} \\ &Y = 5.42337302 - 0.01764762x \end{aligned}$$

$$\begin{aligned} &\text{pH of product after 8 weeks of storage} \\ &Y = 5.46575397 - 0.01553810x \end{aligned}$$

Figure 13. Effect of papaya level (x) and storage time on titratable acidity of product.

$$\begin{aligned} &\text{Titratable acidity of product after 4 weeks of storage} \\ &Y = 28.68444444 + 0.54310000x \end{aligned}$$

Titratable acidity of product after 8 weeks of storage
 $Y = 32.09202381 + 0.49743810x$

Figure 14. Effect of papaya level (x) on propionic acid of product.

mg propionic acid/100 g sample
 $Y = 7.34589319 - 1.27638506x + 0.09784658x^2 - 0.00223202x^3$

APPENDIX 13

VOLATILE FATTY ACIDS OF DRIED BEEF CUBES: TRIAL 1 AND 2

Table 18. Volatile fatty acids of dried beef cubes: trial 1 and 2.

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
Trial 1							
S.0%	P.0%	4	617.337	24.479	345.631	0.040	0.560
S.0%	P.0%	8	367.141	28.918	203.014	0.079	0.553
S.0%	P.5%	4	602.038	12.225	343.259	0.020	0.570
S.0%	P.5%	8	360.399	11.779	199.898	0.033	0.555
S.0%	P.10%	4	454.802	3.918	208.106	0.009	0.458
S.0%	P.10%	8	347.327	5.557	163.874	0.016	0.472
S.0%	P.15%	4	448.503	6.102	168.753	0.014	0.376
S.0%	P.15%	8	307.676	2.806	126.952	0.009	0.413
S.0%	P.20%	4	402.939	5.983	125.876	0.015	0.312
S.0%	P.20%	8	272.542	3.741	97.320	0.014	0.357
S.0%	P.25%	4	423.980	4.727	137.970	0.011	0.325
S.0%	P.25%	8	268.847	2.776	77.486	0.010	0.288
S.2%	P.0%	4	445.771	9.456	268.211	0.021	0.602
S.2%	P.0%	8	262.269	6.263	135.374	0.024	0.516
S.2%	P.5%	4	544.809	9.102	261.764	0.017	0.480
S.2%	P.5%	8	245.699	3.806	115.818	0.015	0.471
S.2%	P.10%	4	465.359	4.828	191.926	0.010	0.412
S.2%	P.10%	8	249.934	3.029	99.502	0.012	0.398
S.2%	P.15%	4	470.317	5.944	178.722	0.013	0.380
S.2%	P.15%	8	234.002	2.963	84.509	0.013	0.361

Table 18 (Continued)

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
S.2%	P.20%	4	478.979	7.835	177.227	0.016	0.370
S.2%	P.20%	8	278.299	5.491	130.193	0.020	0.469
S.2%	P.25%	4	369.241	3.604	145.852	0.010	0.395
S.2%	P.25%	8	276.327	4.135	109.959	0.015	0.398
S.4%	P.0%	4	419.899	10.517	216.988	0.025	0.517
S.4%	P.0%	8	270.195	8.119	136.195	0.030	0.504
S.4%	P.5%	4	337.792	4.608	148.799	0.014	0.441
S.4%	P.5%	8	199.409	2.167	80.003	0.011	0.401
S.4%	P.10%	4	271.713	3.143	94.982	0.012	0.350
S.4%	P.10%	8	219.380	2.969	99.284	0.014	0.453
S.4%	P.15%	4	294.061	3.076	99.705	0.010	0.339
S.4%	P.15%	8	217.436	2.899	82.310	0.013	0.379
S.4%	P.20%	4	228.413	2.636	74.516	0.012	0.326
S.4%	P.20%	8	160.828	1.811	48.548	0.011	0.302
S.4%	P.25%	4	211.890	2.071	69.302	0.010	0.327
S.4%	P.25%	8	237.098	2.387	99.031	0.010	0.418
S.6%	P.0%	4	203.251	3.293	57.682	0.016	0.284
S.6%	P.0%	8	173.024	3.002	64.642	0.017	0.374
S.6%	P.5%	4	135.100	2.358	12.688	0.017	0.094
S.6%	P.5%	8	141.373	3.518	20.599	0.025	0.146
S.6%	P.10%	4	147.154	2.020	22.604	0.014	0.154

Table 18 (Continued)

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
S.6%	P.10%	8	135.594	2.349	29.925	0.017	0.221
S.6%	P.15%	4	151.765	2.385	32.862	0.016	0.217
S.6%	P.15%	8	145.970	2.203	21.628	0.015	0.148
S.6%	P.20%	4	167.778	2.264	28.928	0.013	0.172
S.6%	P.20%	8	133.308	1.769	30.820	0.013	0.230
S.6%	P.25%	4	185.204	2.336	47.717	0.013	0.258
S.6%	P.25%	8	145.382	1.834	26.494	0.013	0.018
S.8%	P.0%	4	148.103	3.200	19.824	0.022	0.134
S.8%	P.0%	8	131.183	2.510	27.097	0.019	0.207
S.8%	P.5%	4	108.187	1.829	11.435	0.017	0.106
S.8%	P.5%	8	99.690	2.098	10.961	0.021	0.110
S.8%	P.10%	4	97.823	1.602	1.911	0.016	0.020
S.8%	P.10%	8	100.722	2.122	3.888	0.021	0.039
S.8%	P.15%	4	93.533	1.628	5.486	0.017	0.059
S.8%	P.15%	8	95.580	1.816	4.342	0.019	0.045
S.8%	P.20%	4	98.950	1.537	5.615	0.016	0.057
S.8%	P.20%	8	113.254	1.664	9.270	0.015	0.082
S.8%	P.25%	4	117.385	2.042	8.164	0.017	0.070
S.8%	P.25%	8	100.109	1.883	4.561	0.019	0.046
S.10%	P.0%	4	178.610	4.415	50.986	0.025	0.285
S.10%	P.0%	8	104.084	1.800	28.461	0.017	0.273

Table 18 (Continued)

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
S.10%	P.5%	4	88.717	1.919	1.856	0.022	0.021
S.10%	P.5%	8	84.357	2.195	2.682	0.026	0.032
S.10%	P.10%	4	79.947	1.729	2.871	0.022	0.036
S.10%	P.10%	8	73.630	1.486	2.331	0.020	0.032
S.10%	P.15%	4	85.733	2.132	2.315	0.025	0.027
S.10%	P.15%	8	80.224	1.442	2.129	0.018	0.027
S.10%	P.20%	4	93.343	2.066	2.218	0.022	0.024
S.10%	P.20%	8	86.264	2.910	3.012	0.034	0.035
S.10%	P.25%	4	95.895	1.839	2.551	0.019	0.027
S.10%	P.25%	8	88.879	1.404	2.162	0.016	0.024
Trial 2							
S.0%	P.0%	4	165.718	47.477	47.844	0.286	0.289
S.0%	P.0%	8	85.482	1.647	7.607	0.019	0.089
S.0%	P.5%	4	13.012	0.484	0.641	0.037	0.049
S.0%	P.5%	8	2.590	0.000	0.000	0.000	0.000
S.0%	P.10%	4	58.351	2.261	2.778	0.039	0.048
S.0%	P.10%	8	4.365	0.000	0.100	0.000	0.023
S.0%	P.15%	4	4.498	0.039	0.000	0.009	0.000
S.0%	P.15%	8	3.315	0.000	0.000	0.000	0.000
S.0%	P.20%	4	4.188	0.037	0.198	0.009	0.047
S.0%	P.20%	8	2.743	0.000	0.000	0.000	0.000

Table 18 (Continued)

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
S.0%	P.25%	4	3.907	0.081	0.217	0.021	0.056
S.0%	P.25%	8	4.943	0.000	0.000	0.000	0.000
S.2%	P.0%	4	195.623	9.532	17.048	0.049	0.087
S.2%	P.0%	8	11.653	0.807	1.830	0.069	0.157
S.2%	P.5%	4	144.011	2.475	4.890	0.017	0.034
S.2%	P.5%	8	74.665	1.652	3.572	0.022	0.048
S.2%	P.10%	4	45.912	1.507	1.055	0.034	0.023
S.2%	P.10%	8	1.285	0.000	0.000	0.000	0.000
S.2%	P.15%	4	133.151	31.052	14.796	0.233	0.111
S.2%	P.15%	8	1.396	0.136	0.681	0.097	0.488
S.2%	P.20%	4	5.385	0.049	0.048	0.009	0.009
S.2%	P.20%	8	42.834	15.610	9.152	0.364	0.214
S.2%	P.25%	4	135.571	2.244	3.354	0.017	0.025
S.2%	P.25%	8	36.790	0.574	0.764	0.016	0.021
S.4%	P.0%	4	103.037	2.128	2.028	0.021	0.020
S.4%	P.0%	8	82.104	2.160	15.444	0.026	0.188
S.4%	P.5%	4	102.861	2.048	1.106	0.020	0.011
S.4%	P.5%	8	2.523	0.000	0.000	0.000	0.000
S.4%	P.10%	4	105.603	1.890	1.331	0.018	0.013
S.4%	P.10%	8	51.971	0.849	0.821	0.016	0.016
S.4%	P.15%	4	66.485	0.699	0.708	0.011	0.011

Table 18 (Continued)

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
S.4%	P.15%	8	54.155	0.882	0.509	0.016	0.009
S.4%	P.20%	4	98.997	1.689	1.137	0.017	0.011
S.4%	P.20%	8	58.645	1.159	0.603	0.020	0.010
S.4%	P.25%	4	103.793	1.490	1.323	0.014	0.013
S.4%	P.25%	8	59.853	1.139	0.844	0.019	0.014
S.6%	P.0%	4	75.272	1.599	0.978	0.021	0.013
S.6%	P.0%	8	47.559	1.156	0.635	0.024	0.013
S.6%	P.5%	4	74.506	1.384	0.871	0.019	0.012
S.6%	P.5%	8	51.633	1.162	0.672	0.023	0.013
S.6%	P.10%	4	74.066	1.392	0.899	0.019	0.012
S.6%	P.10%	8	53.852	1.558	0.625	0.029	0.012
S.6%	P.15%	4	54.553	0.979	0.533	0.018	0.010
S.6%	P.15%	8	50.956	0.958	0.732	0.019	0.014
S.6%	P.20%	4	91.416	1.687	1.202	0.018	0.013
S.6%	P.20%	8	62.668	1.201	0.854	0.019	0.014
S.6%	P.25%	4	97.335	1.747	1.161	0.018	0.012
S.6%	P.25%	8	61.446	1.055	0.711	0.017	0.012
S.8%	P.0%	4	66.888	1.754	1.302	0.026	0.019
S.8%	P.0%	8	38.723	1.049	0.605	0.027	0.016
S.8%	P.5%	4	70.760	1.836	0.968	0.026	0.014
S.8%	P.5%	8	45.205	1.302	0.735	0.029	0.016

Table 18 (Continued)

Treatment		Storage time in weeks	Acetic Acid mg/100g	Propionic Acid mg/100g	Butyric Acid mg/100g	Propionic Acetic Ratio	Butyric Acetic Ratio
S.8%	P.10%	4	67.192	1.753	0.882	0.026	0.013
S.8%	P.10%	8	42.183	0.958	0.667	0.023	0.016
S.8%	P.15%	4	67.705	1.492	0.924	0.022	0.014
S.8%	P.15%	8	42.253	0.853	0.598	0.020	0.014
S.8%	P.20%	4	74.822	1.271	1.023	0.017	0.014
S.8%	P.20%	8	53.477	1.056	0.699	0.020	0.013
S.8%	P.25%	4	73.730	1.313	0.841	0.018	0.011
S.8%	P.25%	8	48.324	0.888	0.805	0.018	0.017
S.10%	P.0%	4	51.882	1.389	0.739	0.027	0.014
S.10%	P.0%	8	34.942	0.886	0.541	0.025	0.015
S.10%	P.5%	4	62.397	1.654	0.804	0.027	0.013
S.10%	P.5%	8	37.305	1.010	0.506	0.027	0.014
S.10%	P.10%	4	50.997	1.087	0.679	0.021	0.013
S.10%	P.10%	8	35.473	0.824	0.690	0.023	0.019
S.10%	P.15%	4	52.042	1.068	0.978	0.021	0.019
S.10%	P.15%	8	31.099	0.701	0.521	0.023	0.017
S.10%	P.20%	4	59.184	1.281	0.920	0.022	0.016
S.10%	P.20%	8	38.076	0.994	0.662	0.026	0.017
S.10%	P.25%	4	59.685	1.285	0.961	0.022	0.016
S.10%	P.25%	8	35.592	0.788	0.701	0.022	0.020

APPENDIX 14

TITRATABLE ACIDITY, TBA NUMBER, MOISTURE, AND pH VALUES OF
DRIED BEEF CUBES: TRIAL 1 AND 2

Table 19. Titratable acidity, TBA number, moisture, and pH values of dried beef cubes: Trial 1 and 2.

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
Trial 1								
S.0%	P.0%	4	26.26	7.456	12.59	5.48	5.70	7.25
S.0%	P.0%	8	29.93	0.522	14.51	5.39	5.70	7.25
S.0%	P.5%	4	31.81	5.898	14.19	5.10	4.90	6.80
S.0%	P.5%	8	32.85	3.688	14.89	5.14	4.90	6.80
S.0%	P.10%	4	37.01	5.379	15.04	4.65	4.70	6.55
S.0%	P.10%	8	45.59	4.686	12.35	4.62	4.70	6.55
S.0%	P.15%	4	40.65	5.066	16.60	4.63	4.60	6.03
S.0%	P.15%	8	50.22	2.362	16.70	4.50	4.60	6.03
S.0%	P.20%	4	41.36	3.186	15.98	4.60	4.60	5.75
S.0%	P.20%	8	46.90	4.195	16.73	4.58	4.60	5.75
S.0%	P.25%	4	37.51	5.766	15.59	4.60	4.50	5.45
S.0%	P.25%	8	47.28	1.557	18.58	4.48	4.50	5.45
S.2%	P.0%	4	27.24	0.423	20.66	5.39	5.40	7.05
S.2%	P.0%	8	30.77	0.604	17.73	5.51	5.40	7.05
S.2%	P.5%	4	27.83	0.256	18.69	5.15	5.00	6.05
S.2%	P.5%	8	40.18	0.436	20.71	4.98	5.00	6.05
S.2%	P.10%	4	43.08	0.402	22.88	4.90	4.75	5.95
S.2%	P.10%	8	46.90	0.456	23.89	4.80	4.75	5.95

Table 19 (Continued)

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.2%	P.15%	4	49.33	0.365	20.96	4.70	4.65	5.30
S.2%	P.15%	8	51.04	0.246	17.24	4.59	4.65	5.30
S.2%	P.20%	4	44.69	0.394	19.98	4.80	4.65	5.20
S.2%	P.20%	8	41.71	0.403	20.48	4.85	4.65	5.20
S.2%	P.25%	4	41.79	0.318	19.91	4.68	4.65	5.10
S.2%	P.25%	8	48.61	0.254	19.73	4.68	4.65	5.10
S.4%	P.0%	4	27.97	0.490	21.05	5.55	5.50	6.80
S.4%	P.0%	8	25.54	0.291	23.11	5.63	5.50	6.80
S.4%	P.5%	4	43.65	0.427	20.29	4.95	4.80	6.25
S.4%	P.5%	8	46.30	0.038	18.78	4.75	4.80	6.25
S.4%	P.10%	4	39.98	0.016	21.89	4.90	4.70	5.60
S.4%	P.10%	8	36.14	0.377	19.87	4.98	4.70	5.60
S.4%	P.15%	4	47.92	0.563	20.05	5.10	4.60	5.20
S.4%	P.15%	8	41.40	0.045	20.69	5.39	4.60	5.20
S.4%	P.20%	4	41.71	0.171	21.62	4.80	4.60	5.03
S.4%	P.20%	8	42.59	0.253	20.37	4.75	4.60	5.03
S.4%	P.25%	4	49.00	0.212	20.93	4.75	4.60	5.03
S.4%	P.25%	8	50.14	0.179	21.08	4.74	4.60	5.03
S.6%	P.0%	4	27.42	0.380	29.71	5.35	5.20	7.23
S.6%	P.0%	8	29.56	0.489	26.95	5.25	5.20	7.23

Table 19 (Continued)

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.6%	P.5%	4	32.14	0.533	26.09	5.00	4.65	6.20
S.6%	P.5%	8	34.79	0.674	25.18	4.98	4.65	6.20
S.6%	P.10%	4	34.18	0.686	25.75	4.92	4.60	5.45
S.6%	P.10%	8	39.71	0.647	27.20	4.94	4.60	5.45
S.6%	P.15%	4	30.62	0.419	26.29	5.00	4.60	5.28
S.6%	P.15%	8	44.06	0.271	22.32	4.85	4.60	5.28
S.6%	P.20%	4	40.83	0.190	23.07	4.90	4.60	5.10
S.6%	P.20%	8	43.24	0.082	25.03	4.72	4.60	5.10
S.6%	P.25%	4	44.10	0.475	27.71	4.85	4.60	5.00
S.6%	P.25%	8	47.98	0.370	21.63	4.79	4.60	5.00
S.8%	P.0%	4	24.70	0.424	28.75	5.40	5.00	6.90
S.8%	P.0%	8	29.56	0.522	27.49	5.39	5.00	6.90
S.8%	P.5%	4	27.83	0.416	27.48	5.25	4.75	6.05
S.8%	P.5%	8	34.10	0.554	28.13	5.12	4.75	6.05
S.8%	P.10%	4	30.87	0.657	28.50	5.13	4.65	5.15
S.8%	P.10%	8	39.02	0.313	26.11	4.91	4.65	5.15
S.8%	P.15%	4	34.01	0.365	27.05	5.05	4.55	4.95
S.8%	P.15%	8	40.96	0.548	26.40	4.90	4.55	4.95
S.8%	P.20%	4	39.40	0.438	27.99	5.00	4.50	4.90
S.8%	P.20%	8	44.90	0.363	24.76	4.86	4.50	4.90

Table 19 (Continued)

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.8%	P.25%	4	36.69	0.613	24.88	5.03	4.50	4.83
S.8%	P.25%	8	44.69	0.495	26.15	4.87	4.50	4.83
S.10%	P.0%	4	23.52	0.737	28.71	5.50	5.10	7.00
S.10%	P.0%	8	25.62	0.424	28.80	5.37	5.10	7.00
S.10%	P.5%	4	26.91	0.672	31.29	5.38	4.95	5.50
S.10%	P.5%	8	28.69	0.321	27.94	5.25	4.95	5.50
S.10%	P.10%	4	30.48	0.285	28.14	5.29	4.80	5.30
S.10%	P.10%	8	33.16	0.561	29.31	5.20	4.80	5.30
S.10%	P.15%	4	30.97	0.737	28.43	5.30	4.70	4.75
S.10%	P.15%	8	33.81	0.179	27.60	5.14	4.70	4.75
S.10%	P.20%	4	36.04	0.489	26.68	5.10	4.60	4.68
S.10%	P.20%	8	34.84	0.373	26.93	5.11	4.60	4.68
S.10%	P.25%	4	37.04	0.453	27.93	5.15	4.60	4.55
S.10%	P.25%	8	36.50	0.269	26.73	4.99	4.60	4.55
Trial 2								
S.0%	P.0%	4	33.63	9.773	19.08	5.54	5.30	7.30
S.0%	P.0%	8	41.75	4.576	16.62	5.20	5.30	7.30
S.0%	P.5%	4	40.77	0.148	27.23	5.50	4.70	6.90
S.0%	P.5%	8	40.16	11.804	25.18	5.84	4.70	6.90
S.0%	P.10%	4	37.69	3.102	23.39	5.15	4.70	6.30

Table 19 (Continued)

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.0%	P.10%	8	40.96	16.009	19.78	5.64	4.70	6.30
S.0%	P.15%	4	35.87	1.605	27.86	5.45	4.70	6.00
S.0%	P.15%	8	24.70	0.531	29.79	6.78	4.70	6.00
S.0%	P.20%	4	39.79	3.418	24.85	5.09	4.60	5.80
S.0%	P.20%	8	43.77	5.191	21.85	5.29	4.60	5.80
S.0%	P.25%	4	42.97	0.675	29.76	5.20	4.60	5.40
S.0%	P.25%	8	39.75	4.058	30.84	6.12	4.60	5.40
S.2%	P.0%	4	27.24	0.000	21.59	5.60	5.50	7.10
S.2%	P.0%	8	30.77	0.398	23.50	6.01	5.50	7.10
S.2%	P.5%	4	27.83	0.124	22.43	5.10	4.70	6.70
S.2%	P.5%	8	40.18	0.224	22.16	5.12	4.70	6.70
S.2%	P.10%	4	43.08	0.000	32.79	5.30	4.70	5.90
S.2%	P.10%	8	46.90	0.485	23.97	5.44	4.70	5.90
S.2%	P.15%	4	49.33	0.000	24.18	5.10	4.70	5.50
S.2%	P.15%	8	51.04	0.108	25.92	5.44	4.70	5.50
S.2%	P.20%	4	44.69	0.000	30.12	5.42	4.70	5.30
S.2%	P.20%	8	41.71	0.363	23.13	5.19	4.70	5.30
S.2%	P.25%	4	41.79	0.140	22.45	4.87	4.60	5.10
S.2%	P.25%	8	48.61	0.116	24.23	5.14	4.60	5.10
S.4%	P.0%	4	30.95	0.297	25.49	5.49	5.20	7.00

Table 19 (Continued)

Treatment		Storage time in weeks	Titrateable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.4%	P.0%	8	33.54	0.493	25.05	5.43	5.20	7.00
S.4%	P.5%	4	33.87	0.194	25.91	5.24	4.70	6.60
S.4%	P.5%	8	35.63	0.208	30.39	5.99	4.70	6.60
S.4%	P.10%	4	37.16	0.251	26.03	5.23	4.70	6.10
S.4%	P.10%	8	36.69	0.312	27.32	5.35	4.70	6.10
S.4%	P.15%	4	38.06	0.000	28.36	5.10	4.70	5.60
S.4%	P.15%	8	42.16	0.239	24.41	5.39	4.70	5.60
S.4%	P.20%	4	41.65	0.109	24.62	5.10	4.70	5.40
S.4%	P.20%	8	38.59	0.312	25.68	5.20	4.70	5.40
S.4%	P.25%	4	42.53	0.000	24.50	5.00	4.60	5.10
S.4%	P.25%	8	41.94	0.192	23.48	5.23	4.60	5.10
S.6%	P.0%	4	27.42	0.016	27.52	5.58	5.20	7.00
S.6%	P.0%	8	29.56	0.312	27.53	5.60	5.20	7.00
S.6%	P.5%	4	32.14	0.350	27.11	5.45	4.80	6.70
S.6%	P.5%	8	34.79	0.148	26.07	5.60	4.80	6.70
S.6%	P.10%	4	34.18	0.489	28.50	5.45	4.80	6.10
S.6%	P.10%	8	39.71	0.502	26.33	5.52	4.80	6.10
S.6%	P.15%	4	30.62	0.000	27.30	5.46	4.70	5.70
S.6%	P.15%	8	44.06	0.459	27.12	5.51	4.70	5.70

Table 19 (Continued)

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.6%	P.20%	4	40.83	0.473	26.43	5.30	4.70	5.30
S.6%	P.20%	8	43.24	0.304	25.84	5.50	4.70	5.30
S.6%	P.25%	4	44.10	0.238	24.52	5.20	4.70	4.90
S.6%	P.25%	8	47.98	0.355	24.27	5.40	4.70	4.90
S.8%	P.0%	4	23.56	0.372	26.69	5.70	5.50	7.10
S.8%	P.0%	8	27.99	0.062	28.57	5.79	5.50	7.10
S.8%	P.5%	4	28.13	0.000	26.77	5.60	5.40	6.80
S.8%	P.5%	8	32.42	0.208	25.50	5.51	5.40	6.80
S.8%	P.10%	4	31.95	0.218	25.10	5.50	5.20	5.80
S.8%	P.10%	8	32.28	0.640	24.61	5.60	5.20	5.80
S.8%	P.15%	4	30.14	0.000	27.08	5.55	5.10	5.50
S.8%	P.15%	8	34.57	0.355	25.49	5.50	5.10	5.50
S.8%	P.20%	4	36.99	0.109	25.06	5.40	5.00	5.20
S.8%	P.20%	8	36.69	0.231	25.39	5.50	5.00	5.20
S.8%	P.25%	4	35.79	0.287	25.82	5.35	4.90	5.10
S.8%	P.25%	8	36.18	0.000	24.78	5.53	4.90	5.10
S.10%	P.0%	4	24.60	0.349	27.99	5.61	5.50	7.40
S.10%	P.0%	8	24.11	0.805	28.26	5.90	5.50	7.40
S.10%	P.5%	4	29.20	0.024	28.69	5.55	5.50	6.40
S.10%	P.5%	8	28.58	0.683	26.77	5.73	5.50	6.40

Table 19 (Continued)

Treatment		Storage time in weeks	Titratable Acidity meg NaOH/100g	TBA Number	Percent of Moisture	pH of Meat after Drying	pH of Solu- tion after Treatment	pH of Solu- tion before Treatment
S.10%	P.10%	4	28.89	0.436	27.84	5.60	5.50	5.60
S.10%	P.10%	8	29.28	0.234	26.45	5.74	5.50	5.60
S.10%	P.15%	4	29.99	0.256	26.47	5.55	5.40	5.50
S.10%	P.15%	8	30.52	0.493	27.86	5.72	5.40	5.50
S.10%	P.20%	4	35.28	0.251	26.43	5.45	5.30	5.10
S.10%	P.20%	8	31.03	0.208	26.21	5.61	5.30	5.10
S.10%	P.25%	4	34.85	0.000	24.08	5.49	5.20	5.00
S.10%	P.25%	8	37.20	0.162	25.41	5.49	5.20	5.00

APPENDIX 15

MICROBIAL LOAD^a OF MEAT AFTER 48 HOURS OF CURING, BEFORE DRYING: TRIAL 1 AND 2

Table 20. Microbial load^a of meat after 48 hours of curing, before drying: Trial 1 and 2 (Values in log numbers).

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
Trial 1						
S.0% P.0%	7.94	7.20 (est.)	5.26	0.00	4.66	2.26
S.0% P.5%	8.49	7.15 (est.)	6.59	3.00	Lost	2.45
S.0% P.10%	8.18	5.30	3.04	1.00	3.49	2.38
S.0% P.15%	8.30	6.58	3.23	3.00	3.08	2.04
S.0% P.20%	8.62	5.40	3.04	1.00	3.69	1.90
S.0% P.25%	8.23	5.36	4.08	0.00	4.15	1.00
S.2% P.0%	8.91	6.62 (est.)	4.23	0.00	4.70	2.18
S.2% P.5%	7.90	6.15	6.28	0.00	6.52	2.28
S.2% P.10%	7.92	6.08	6.65	0.00	2.76	2.00
S.2% P.15%	8.18	6.15	3.23	0.00	Lost	1.60
S.2% P.20%	8.20	6.11	3.20	0.00	4.11	1.30
S.2% P.25%	8.00	7.26 (est.)	3.79	2.00	3.08	1.30

Table 20 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.4% P.0%	7.94	6.11	6.41	0.00	3.57	1.60
S.4% P.5%	8.88	6.40	6.36	3.00	3.23	1.78
S.4% P.10%	8.34	6.00	4.65	1.00	3.34	1.48
S.4% P.15%	7.75	6.15	6.00	0.00	4.79	1.30
S.4% P.20%	7.81	6.11	6.46	0.00	3.51	1.00
S.4% P.25%	8.65	6.15	5.46	0.00	3.41	1.00
S.6% P.0%	8.00	Lost	5.51	0.00	4.08	1.48
S.6% P.5%	8.28	6.15	5.89	2.00	3.23	1.48
S.6% P.10%	7.99	6.15	5.80	0.00	3.18	1.00
S.6% P.15%	7.81	6.00	5.23	0.00	3.18	<1.00
S.6% P.20%	8.20	6.00	5.23	4.30	3.48	<1.00
S.6% P.25%	8.18	6.04	6.11	3.30	3.28	<1.00
S.8% P.0%	8.20	5.20	3.81	0.00	3.54	<1.00
S.8% P.5%	7.97	4.04	3.61	4.48	3.00	<1.00

Table 20 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.8% P.10%	7.64	3.60	3.72	0.00	3.54	1.00
S.8% P.15%	8.28	5.72	5.11	0.00	4.94	1.30
S.8% P.20%	7.62	3.58	3.53	3.30	3.00	<1.00
S.8% P.25%	7.97	4.20	3.83	0.00	2.59	<1.00
S.10% P.0%	8.04	5.90	6.36	3.00	5.04	<1.00
S.10% P.5%	7.68	3.43	3.85	1.30	4.11	<1.00
S.10% P.10%	8.04	2.00	3.32	3.00	3.11	<1.00
S.10% P.15%	8.15	2.78	3.11	0.00	3.28	<1.00
S.10% P.20%	7.87	4.48	3.85	2.00	3.56	<1.00
S.10% P.25%	8.18	3.51	3.75	1.00	3.67	<1.00
Trial 2						
S.0% P.0%	9.54	7.26	5.87	0.00	>1.00	1.30
S.0% P.5%	9.40	7.60	5.63	0.00	<1.00	<1.00
S.0% P.10%	7.69	5.90	3.46	0.00	<1.00	1.48

Table 20 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.0% P.15%	10.08	6.58	4.61	0.00	2.15	<1.00
S.0% P.20%	8.18	6.66	6.26	0.00	<1.00	<1.00
S.0% P.25%	7.67	6.95	6.36	0.00	<1.00	<1.00
S.2% P.0%	8.04	8.26	6.11	0.00	3.60	1.70
S.2% P.5%	7.68	7.99	5.93	0.00	1.30	<1.00
S.2% P.10%	7.89	8.28	5.86	0.00	2.30	2.15
S.2% P.15%	7.72	8.36	5.67	0.00	<1.00	1.78
S.2% P.20%	7.95	8.53	5.80	0.00	<1.00	<1.00
S.2% P.25%	8.04	8.00	6.18	0.00	<1.00	<1.00
S.4% P.0%	7.48	8.54	5.75	0.00	2.30	<1.00
S.4% P.5%	7.95	8.41	5.67	0.00	2.60	<1.00
S.4% P.10%	8.08	8.08	5.77	0.00	2.48	1.48
S.4% P.15%	8.41	8.63	5.98	0.00	1.70	<1.00
S.4% P.20%	8.43	7.48	6.36	0.00	2.00	1.00

Table 20 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.4% P.25%	7.85	7.77	6.32	0.00	1.78	2.15
S.6% P.0%	8.11	9.43	6.18	1.00	2.60	<1.00
S.6% P.5%	7.95	9.20	5.95	0.00	2.70	<1.00
S.6% P.10%	8.04	8.08	5.00	0.00	2.15	<1.00
S.6% P.15%	8.00	8.11	5.04	0.00	1.85	1.60
S.6% P.20%	8.58	7.40	6.04	0.00	3.04	2.20
S.6% P.25%	8.28	7.41	5.38	0.00	3.43	1.48
S.8% P.0%	8.18	7.36	6.00	0.00	3.30	1.30
S.8% P.5%	8.15	7.08	6.04	0.00	2.48	1.48
S.8% P.10%	8.04	8.15	6.11	0.00	3.60	1.90
S.8% P.15%	8.08	7.20	5.95	0.00	3.48	1.70
S.8% P.20%	8.78	7.26	6.40	0.00	2.75	1.78
S.8% P.25%	8.66	7.45	6.43	0.00	1.60	<1.00
S.10% P.0%	8.11	6.41	5.74	0.00	4.78	<1.00

Table 20 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.10% P.5%	7.68	6.41	5.08	0.00	4.95	<1.00
S.10% P.10%	8.48	6.15	3.49	0.00	3.00	<1.00
S.10% P.15%	7.41	4.00	4.81	0.00	3.90	<1.00
S.10% P.20%	6.90	6.00	4.83	0.00	1.78	1.85
S.10% P.25%	7.66	6.28	5.53	0.00	2.11	<1.00

^a From Castro-Espinoza (1982).

APPENDIX 16

MICROBIAL LOAD^a OF MEAT AFTER DRYING AND ONE MONTH STORAGE: TRIAL 1 AND 2

Table 21. Microbial load^a of meat after drying and one month storage: Trial 1 and 2
(Values in log numbers).

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
Trial 1						
S.0% P.0%	4.08	<1.00	<1.00	1.00	<1.00	<1.00
S.0% P.5%	3.20	<1.00	1.60	<1.00	<1.00	<1.00
S.0% P.10%	4.73	<1.00	<1.00	<1.00	<1.00	<1.00
S.0% P.15%	3.88	<1.00	<1.00	1.00	<1.00	<1.00
S.0% P.20%	<1.00	<1.00	<1.00	1.00	<1.00	<1.00
S.0% P.25%	2.94	<1.00	<1.00	<1.00	<1.00	<1.00
S.2% P.0%	2.75	<1.00	<1.00	1.00	<1.00	<1.00
S.2% P.5%	3.82	<1.00	<1.00	<1.00	<1.00	<1.00
S.2% P.10%	4.43	4.51	3.36	<1.00	2.70	<1.00
S.2% P.15%	3.95	<1.00	<1.00	1.78	1.78	<1.00
S.2% P.20%	3.53	<1.00	<1.00	<1.00	<1.00	<1.00
S.2% P.25%	3.68	<1.00	<1.00	1.00	<1.00	<1.00

Table 21 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.4% P.0%	3.86	<1.00	<1.00	<1.00	<1.00	<1.00
S.4% P.5%	<1.00	<1.00	<1.00	1.00	<1.00	<1.00
S.4% P.10%	3.77	<1.00	<1.00	<1.00	<1.00	<1.00
S.4% P.15%	2.68	<1.00	<1.00	<1.00	<1.00	<1.00
S.4% P.20%	2.40	<1.00	<1.00	1.00	<1.00	<1.00
S.4% P.25%	4.08	<1.00	<1.00	<1.00	<1.00	<1.00
S.6% P.0%	3.30	<1.00	<1.00	1.48	<1.00	<1.00
S.6% P.5%	3.20	<1.00	<1.00	<1.00	<1.00	<1.00
S.6% P.10%	3.56	<1.00	<1.00	<1.00	<1.00	<1.00
S.6% P.15%	3.73	<1.00	<1.00	<1.00	<1.00	<1.00
S.6% P.20%	3.86	<1.00	<1.00	1.00	<1.00	<1.00
S.6% P.25%	3.04	<1.00	<1.00	<1.00	<1.00	<1.00
S.8% P.0%	3.62	<1.00	<1.00	<1.00	<1.00	<1.00
S.8% P.5%	2.83	<1.00	<1.00	<1.00	<1.00	<1.00

Table 21 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.8% P.10%	2.72	<1.00	<1.00	<1.00	<1.00	<1.00
S.8% P.15%	3.82	<1.00	<1.00	1.30	<1.00	<1.00
S.8% P.20%	3.61	<1.00	<1.00	1.48	<1.00	<1.00
S.8% P.25%	2.83	<1.00	<1.00	1.78	<1.00	<1.00
S.10% P.0%	2.60	<1.00	<1.00	<1.00	<1.00	<1.00
S.10% P.5%	3.72	<1.00	<1.00	1.30	<1.00	<1.00
S.10% P.10%	3.92	<1.00	<1.00	1.00	<1.00	<1.00
S.10% P.15%	2.74 (est.)	<1.00	<1.00	<1.00	<1.00	<1.00
S.10% P.20%	3.66	<1.00	<1.00	1.00	<1.00	<1.00
S.10% P.25%	2.28	<1.00	<1.00	<1.00	<1.00	<1.00
Trial 2						
S.0% P.0%	6.41	<1.00		3.28	<1.00	<1.00
S.0% P.5%	Too moldy	<1.00		Lost	<1.00	<1.00
S.0% P.10%	5.11	<1.00		2.71	<1.00	<1.00

Table 21 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.0% P.15%	4.85	<1.00		4.89	<1.00	<1.00
S.0% P.20%	6.08	<1.00		2.51	<1.00	<1.00
S.0% P.25%	5.49	<1.00		3.75	<1.00	<1.00
S.2% P.0%	6.45	<1.00		2.63	<1.00	<1.00
S.2% P.5%	5.72	<1.00		2.48	<1.00	<1.00
S.2% P.10%	6.46	<1.48	<1.00	1.78	<1.00	<1.00
S.2% P.15%	6.08	<1.00	0.00	<1.00	<1.00	<1.00
S.2% P.20%	6.30	<1.00		2.54	<1.00	<1.00
S.2% P.25%	5.20	<1.00		2.11	<1.00	<1.00
S.4% P.0%	6.00	<1.00		2.15	<1.00	<1.00
S.4% P.5%	6.97	<1.00		2.15	<1.00	<1.00
S.4% P.10%	6.72	<1.00		1.00	<1.00	<1.00
S.4% P.15%	6.32	<1.00		<1.00	<1.00	<1.00
S.4% P.20%	5.75	<1.00	1.43	1.30	<1.00	<1.00

Table 21 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.4% P.25%	5.40	<1.00		<1.00	<1.00	<1.00
S.6% P.0%	6.93	<1.00		1.00	<1.00	<1.00
S.6% P.5%	6.36	<1.00		1.30	<1.00	<1.00
S.6% P.10%	6.78	<1.00		1.00	<1.00	<1.00
S.6% P.15%	6.67	<1.00		1.00	<1.00	<1.00
S.6% P.20%	Much Bacillus	<1.00		<1.00	<1.00	<1.00
S.6% P.25%	5.69	<1.00		<1.00	<1.00	<1.00
S.8% P.0%	5.60	<1.00		1.95	<1.00	<1.00
S.8% P.5%	6.40	<1.00		<1.00	<1.00	<1.00
S.8% P.10%	4.67	<1.00		1.30	<1.00	<1.00
S.8% P.15%	6.80	<1.00	0.00	1.00	<1.00	<1.00
S.8% P.20%	6.49	<1.00	0.00	1.00	<1.00	<1.00
S.8% P.25%	5.60	<1.00	0.00	1.00	<1.00	<1.00
S.10% P.0%	6.32	<1.00	0.00	1.00	<1.00	<1.00

Table 21 (Continued)

Treatment	Mesophiles (TPC)	Coliforms	Yeast	Molds	Staph.	Clostridium perfringens
S.10% P.5%	4.83	<1.00		1.48	<1.00	<1.00
S.10% P.10%	5.60	<1.00		1.00	<1.00	<1.00
S.10% P.15%	5.75	<1.00		<1.00	<1.00	<1.00
S.10% P.20%	6.68	<1.00		1.00	<1.00	<1.00
S.10% P.25%	4.64	<1.00		<1.00	<1.00	<1.00
Trial 1: F: 37	5.08	<1.00		<1.00	<1.00	<1.00
Trial 2: F: 38	6.32	<1.00		<1.00	<1.00	<1.00

^aFrom Castro-Espinoza (1982).

VITA

Collins Nkeoma Ubbaonu was born on November 8, 1948 to Ubbaonu Abba Duru and Esialu Nwanyinonu Ubbaonu in Umuchima, Orlu Nigeria. He came to the United States in August, 1974, and attended Berea College in Kentucky from 1974 to 1978. There he received the Bachelor of Arts degree in Chemistry. He enrolled at The University of Tennessee, Knoxville in September, 1978. There he received a Master of Science degree and a Doctor of Philosophy degree in Food Technology and Science in March 1980 and March 1982, respectively. While in The University of Tennessee he was a member of Phi Tau Sigma and Gamma Sigma Delta honor societies and also a member of American Oil Chemists Society.