

MODIFIED ATMOSPHERE PACKAGING OF
GROUND TURKEY THIGH MEAT

by

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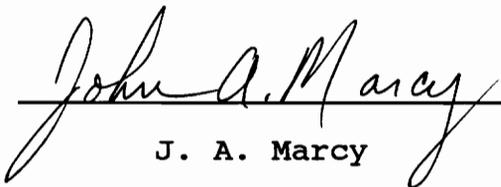
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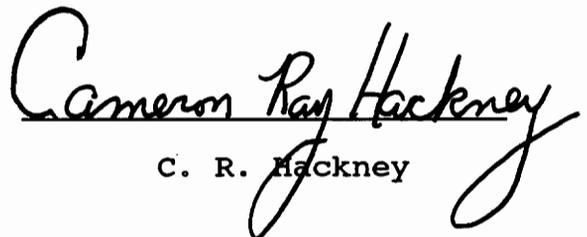
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(ABSTRACT)

The objectives of this study were to develop MAP conditions, using mixtures of oxygen (O₂) and carbon dioxide (CO₂), to prolong the shelf-life of ground turkey thigh meat. The effect of fat level and effectiveness of natural antioxidants were evaluated.

Product quality was determined semi-weekly by sensory, microbial, chemical, and instrumental analysis to evaluate rancidity, and sensory flavor changes. Thiobarbituric acid (TBA) tests were conducted to objectively measure changes in oxidative rancidity. Microbial analysis included psychrotrophic, lactic acid, and anaerobic bacteria enumerations, pH determinations were conducted to evaluate the effects of each treatment on the meat. Instrumentation color analysis CIE L* a* b* values were determined to measure color changes.

Test results indicate the pH changed significantly only in the air packaged samples. Psychrotrophic, lactic acid and anaerobic bacteria counts were significantly lower

($P < 0.05$) in the 100% CO₂ packaged samples, than all other treatments and the control. Low TBA values, less than 4, were found with the 100% CO₂ samples. Sensory evaluation found the 80% O₂/20% CO₂ and 60% O₂/40% CO₂ packages were no longer acceptable at day 14, and air samples were unacceptable at day 18. The 100% CO₂ sample maintained acceptable over-all taste throughout the test period. Colorimeter values did show the 100% CO₂ atmosphere caused discoloration of the product during the first week. Fat level did not affect microorganism growth or shelf-life extension.

Rosemary oleoresin was effective as an antioxidant. TBA values of rosemary treated samples remained under 1.0 for the entire 28-day storage period.

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My parents, Don and Tina Sonneville, deserve any royalties from this thesis. Without their faith in my abilities, I would never have gone to college initially and may not have reached this point in my life.

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difficult).

I could write a thesis about all the people who have helped me get through my years (too many) in college. Instead, I will just thank my family and friends in Illinois, Northern Virginia and Blacksburg for all their help.

I dedicate this thesis and my life's work to the Lord, from whom all good things come. "I can do all things through Him who strengthens me" (Philippians 4:13).

TABLE OF CONTENTS

	<u>page</u>
I. INTRODUCTION	1
II. LITERATURE REVIEW	3
1. Poultry	3
1.1. Microbiological Spoilage	3
1.2. Oxidative Spoilage	5
1.3. Packaging History	8
2. Modified Atmosphere Packaging	8
2.1. Definition	8
2.2. History	9
2.3. Gases Utilized	9
2.3.1. Nitrogen	10
2.3.2. Oxygen	10
2.3.3. Carbon Dioxide	11
2.3.3.1. Effect of CO ₂ on Microorganisms	12
2.3.3.2. Effect of CO ₂ on Meat Color	15
2.4. Advantages and Disadvantages	17
3. Naturally Occurring Antioxidants	17
3.1. Rosemary Oleoresin	17
III. MATERIALS AND METHODS	20
1. Preparation and Packaging of Ground Meat	20
2. Analysis of headspace gas composition	21
3. Microbiological testing of ground turkey meat..	22
3.1. Psychrotrophic Bacteria Enumeration	22
3.2. Anaerobic Bacteria Enumeration	22
3.3. Lactic Acid Bacteria Enumeration	23
4. Chemical and physical analysis	23
4.1. Fat Level Determination	23
4.2. pH Measurement	24
4.3. Color Evaluation	24
4.4. TBA Analysis for Rancidity	24
4.4.1. Preparation of Samples	25
4.4.2. TBA Assay	25
4.4.3. Standard Curve Preparation	26
4.4.4. Percent Recovery Determination ..	26
4.4.5. Calculation of TBA Values	27
5. Sensory Analysis of Ground Turkey Meat	27
6. Rosemary Oleoresin Antioxidant	28
7. Statistical Analysis	29
IV. RESULTS AND DISCUSSION	30
1. Headspace Gas Analysis	30
2. Fat Level Determination	30

TABLE OF CONTENTS (cont)

	<u>page</u>
3. pH Measurement Analysis	34
4. Microbial Analysis	34
5. Color Measurement Analysis	40
6. TBA Analysis	46
7. Sensory Evaluation Analysis	48
8. Rosemary Oleoresin Results	51
8.1. Headspace Gas Analysis	51
8.2. pH Measurement Analysis	51
8.3. Microbiological Analysis	56
8.4. Color Measurement Analysis	56
8.5. TBA Analysis	56
V. SUMMARY AND CONCLUSIONS	64
VI. REFERENCES	66
VII. APPENDIX	75
VITA	77

LIST OF FIGURES

<u>Figure</u>		<u>page</u>
1	Headspace Oxygen Levels	31
2	Headspace Carbon Dioxide Levels	32
3	Headspace Nitrogen Levels	33
4	pH Values	35
5	Lactic Acid Bacteria	36
6	Psychrotrophic Bacteria Results	37
7	Anaerobic Bacteria Results	38
8	L* Color Values	42
9	a* Color Values	43
10	b* Color Values	45
11	TBA Values	47
12	Rancidity (Sensory) Results	49
13	Over-all Flavor (Sensory) Results	50
14	Headspace Oxygen Levels, Rosemary Treatment	52
15	Headspace Carbon Dioxide Levels, Rosemary Treatment	53
16	Headspace Nitrogen Levels, Rosemary Treatment	54
17	pH Values, Rosemary Treatment	55
18	Lactic Acid Bacteria Results, Rosemary Treatment .	57
19	Psychrotrophic Bacteria Results, Rosemary Treatment	58
20	Anaerobic Bacteria Results, Rosemary Treatment ...	59
21	L* Color Values, Rosemary Treatment	60
22	a* Color Values, Rosemary Treatment	61

LIST OF FIGURES

<u>Figure</u>		<u>page</u>
23	b* Color Values, Rosemary Treatment	62
24	TBA Values, Rosemary Treatment	63

I. INTRODUCTION

Consumption of turkey meat is expected to increase to 30 pounds per person by 1993, according to the National Turkey Federation. In 1980, consumption per person was 10 pounds and 17 pounds per person in 1988 (Waldrop, 1989). This dramatic increase is said to be a direct result of marketing exploitation to health conscious consumers.

Turkey meat fits into the low-fat, low-calorie, low-cholesterol diets desired by consumers. Not only does turkey contain less calories and fat than beef, the lipids are less saturated than that of beef. Of the lipids in turkey only 28-33% are saturated, while beef contains 40-71% saturated fatty acids (Hultin, 1985).

Ground, fresh, turkey thigh meat is being marketed by poultry processors to compete with other meat products such as ground beef. The shelf-life of this product is limited, however, due to microbial spoilage and oxidative rancidity of the fat.

Use of chemical or synthetic preservatives has been used to extend the shelf-life of food products. To the health conscious consumer, this type of preservation is no longer acceptable. Consumers now prefer more fresh, refrigerated food items. Modified atmosphere packaging (MAP) is a technology used previously and is well known for extending the shelf-life of some foods, including poultry

products.

Equipment, material and gas shipment for vacuum/controlled atmosphere/modified packaging markets totaled \$1.1 billion in 1990. This market is expected to grow 9.8% annually, reaching \$1.8 billion by 1995. Raw and cooked poultry is and will remain the single largest outlet for gas packaging technology (Anonymous, 1991).

At present, it is not known what the optimal conditions are for the storage of ground poultry products. Each food product needs to be tested to evaluate which gas compositions are correct for extended storage in modified atmosphere.

The first objective of this study was to develop modified atmosphere conditions that would prolong the shelf-life of fresh, ground turkey thigh meat. Mixtures of oxygen (O_2) and carbon dioxide (CO_2) were tested to determine which mixture best protects the sensory qualities of color, flavor and odor of fresh meat and inhibit spoilage due to microorganisms. The gas compositions tested were: 80% O_2 /20% CO_2 , 60% O_2 /40% CO_2 , and 100% CO_2 . An air treatment was used as a control. Other objectives were to: determine the effect of fat level on the stability of the meat, and evaluate the effectiveness of rosemary oleoresin as a natural antioxidant.

II. LITERATURE REVIEW

1. Poultry

Poultry is a valuable source of protein without the fat levels found in beef. Turkey thigh meat without skin contains approximately 20% protein, 20% fat and 60% moisture (Ockerman, 1981). The water activity (a_w), water available for microbial growth, of fresh turkey meat is 0.98 (Bryan, 1980) and has a pH of 5.5 to 6.4 (Ockerman, 1981). These properties are very important in regard to microbial growth because most bacteria on the meat after slaughter will grow when the a_w is above 0.91 (Jay, 1986) and in a pH range of 5-8. Turkey can be a haven for bacteria if the proper handling and storage procedures are not applied.

1.1. Microbiological Spoilage

Freshly slaughtered poultry carcasses typically have a population of 10^2 - 10^4 bacteria per square inch. The predominant microflora on these carcasses are mesophilic in nature: coliforms, E. coli, enterococci, Staphylococcus aureus, Clostridium perfringens and salmonellae (Cunningham, 1987). During refrigerated storage, the carcass flora shifts toward a psychrotrophic flora of the Pseudomonas and Acinetobacter species (Johnston and Tompkin, 1984). Psychrotrophic bacteria are the major concern in regard to

shelf-life of poultry food products. These bacteria come into the processing plant on the feet and feathers of the birds. Once these bacteria come in contact with surface areas of equipment and tools and into the chilling water, they multiply.

Spoilage of refrigerated poultry usually exhibits an increased pH due to growth of bacteria which release ammonia and other compounds. Off-odors and off-flavors are a result of accumulation of bacterial endpoints that are noticeable when psychrotrophic plate counts exceed 10^7 log numbers/cm². At 10^8 log numbers/cm² slime formation occurs due to coalescence of bacterial colonies (Jay, 1986). Fresh, refrigerated poultry will usually spoil in approximately 14 days or less (Hotchkiss, 1989).

USDA does not mandate a limit for pathogens such as salmonellae in raw poultry. This is because the raising and transportation of poultry creates a situation where it is difficult to lower bacterial contamination (Vanderzant, 1985). These bacteria do not pose a problem if proper food-handling practices are observed.

Clostridium perfringens and Staphylococcus aureus may be present on poultry carcasses after slaughter, but they do not grow at low storage temperatures. They are also not very competitive against psychrotrophic bacteria, making

them a minor concern in regard to poultry products (Johnston and Tompkin; 1984).

Salmonella, and Campylobacter are inhibited by refrigeration temperatures, and cannot withstand heat treatments of 160°F. If the meat is cooked properly, there is no cause for concern.

Factors influencing the type of microbial spoilage in meats include: inherent meat pH, addition of salt, sugar, nitrite, smoke, acidulants, and whether the meat is dried, fermented or heated. Type and rate of spoilage after processing are influenced by: type of packaging materials, storage temperature, surviving or contaminating microorganisms and final composition of the product (Johnston and Tompkin; 1984).

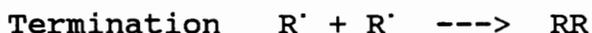
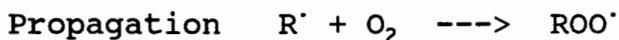
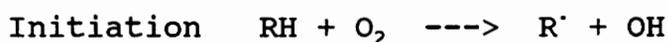
1.2 Oxidative Spoilage

Another cause of spoilage in poultry is due to lipid oxidation. Oxidation involves the reaction of oxygen with unsaturated fatty acids in lipids. The most abundant polyunsaturated fatty acids found in poultry include oleic and linoleic acids (Ockerman, 1981). The double bonds in polyunsaturated fatty acids are not as stable as single bonds and are more susceptible to oxidation reactions (Melton, 1983). These double bonds react with O₂ to form hydroperoxides. These hydroperoxides do not directly

contribute to the undesirable flavors and odors of autoxidized foods. The off-odors and off-flavors are due to secondary substances derived from various reactions and further oxidation of the peroxides and their degradation products (Lundberg, 1962).

The mechanism of oxidation involves three steps (1) initiation - the formation of free radicals; (2) propagation - the reaction of free radicals; and (3) termination - the formation of non-radical, deterioration, products.

The steps involved in autoxidation are illustrated below:



Where RH is an unsaturated fatty acid; R' is a free radical; and ROOH is hydroperoxide, a major oxidation product that decompose to form compounds responsible for off-flavors (Nawar, 1985). The aldehydes, mostly short chains, and short chain acids derived from further oxidation of aldehydes are responsible for the off-odors and off-flavors of rancid foods (Lundberg, 1962).

The thiobarbituric acid test (TBA) can be employed to

detect lipid oxidation. TBA reacts with malondialdehyde, producing a red hue, which is then evaluated with a spectrophotometer.

Inhibition of the oxidation rate is achieved by several methods (Ockerman, 1981):

- a) addition of antioxidants to the fat portion of the meat,
- b) exclusion of O₂ from the packaging headspace,
- c) prevention of light from penetrating the packaging material,
- d) maintenance of refrigeration temperatures at all times after slaughter,
- e) hydrogenation of unsaturated fatty acids,
- f) removal of all metals which may act as a catalyst to the oxidation reaction (i.e. NaCl), and
- g) storage of meat in a moisture-free environment.

If O₂ were eliminated from MAP products, spoilage due to oxidation would be greatly reduced as long as autoxidation has not been initiated. In studies by Seman et al, (1988), panelists did not detect off-odors in CO₂ flushed venison loins until week 18. Sensory analysis of broiler carcasses (Gill et al, 1990) packaged in carbon dioxide and held at 3°C showed no indication of spoilage until week six when a slight sour flavor was detected.

1.3. Packaging History

The poultry industry got its start in the late 1940s after World War II. Birds were packaged, uneviscerated, in wooden barrels with crushed ice. In the 1950s, processing plants were eviscerating the birds and packaging them whole in wire-bound, wooden containers with crushed ice. The retailers then cut up the birds and packaged them in formed trays with transparent film overwrap. During the 1960's, the poultry plants began to take over the cutting and prepackaging of portions frequently purchased by consumers. Paraffin lined cardboard containers were used for shipping instead of wooden crates (Maurer, 1991). Poultry packaging of today allows the meat to be transported in individually wrapped trays, which are stacked and shipped in a cardboard shipping box, and transported in refrigerated vehicles.

The major problems associated with the packaging techniques of the past include microbial contamination of the birds by the ice, and the added weight of the ice during transportation. An addition of 25% more payload per truck has been reported when ice is not used to pack poultry (Timmons, 1976).

2.1 Modified Atmosphere Packaging

"MAP is the enclosure of food products in high gas-barrier materials, in which the gaseous environment has been

changed once to slow respiration rates, reduce microbiological growth, retard enzymatic spoilage - with the intent of extending shelf-life" (Koski, 1988).

2.2. History

The use of modified atmosphere began in the 1930s, primarily with bulk shipments of meat and produce. By 1938, 60% of all beef from New Zealand was shipped in CO₂-enriched storage areas (Smith et al, 1990). The packaging of individual portions started in the 1950s with coffee, meat and fish. By the 1960s, researchers in West Germany and Denmark were experimenting with gas flushing with nitrogen (N₂). Application of this technology on a broad scale did not occur until 1981 when the Marks and Spencer grocery store chain of England packaged fresh meat in gas-flushed containers (Inns, 1987). MAP is now being applied in many different food industries including: fruit, vegetable, fish, poultry and bakery, to name a few.

2.3. Gases Utilized in MAP

In most MAP applications, the gases used are N₂, O₂ and CO₂. There is no correct atmosphere for MAP. Different compositions of several gases may be used or a single gas might be used. The composition depends on the product being

packaged, the packaging material being used, and expected storage conditions.

2.3.1. Nitrogen

The role of N_2 is to serve as an inert filler gas. It is used to displace the air present, and therefore, serves to inhibit microorganisms that require O_2 to proliferate. N_2 also keeps flexible packages from collapsing when less inert gases are utilized by the product inside the container. Hotchkiss (1989) recommended 26% N_2 in the MAP package for optimal shelf-life of fresh poultry.

2.3.2. Oxygen

Use of O_2 in MAP of poultry is often considered necessary because of the need for a bright red color produced when the myoglobin present is in the oxidized state. As little as 5% O_2 is needed to provide the desirable bright red color (bloom) of meat (Brody, 1989) but O_2 levels of 60-80% (Inns, 1987) will maintain the oxymyoglobin color for a longer period of time, increasing the period of saleability (Inns, 1987; Baker et al, 1985).

However, O_2 is the one gas most often avoided in modified atmospheres because of oxidative effects and its stimulation of aerobic bacteria. Lipid oxidation can occur when as little as 0.1% of fatty acids and O_2 are present in

foods (Inns, 1987). Since many spoilage bacteria need O₂ to grow, it would be helpful if it were eliminated from the gas mixture. Aerobic bacteria are capable of growth in oxygen concentrations up to 40% (Brody, 1989). Oxygen concentrations of 50% and above will not support growth of aerobic spoilage bacteria (Zagory and Kader, 1988).

2.3.3. Carbon Dioxide

CO₂ is used due to its inhibitory effect on growth of microorganisms, separate from exclusion of O₂. Dixon and Kell (1989) reported that over 4,000 scientific papers have been written on the use of CO₂ for MAP applications, but in their review of the mechanism of CO₂ inhibition of microorganisms, they conclude the mechanism is still unknown. Several theories have been proposed which include:

a) A decrease in the pH of the food product due to absorption of CO₂ into product surface. The inhibitory effects of CO₂ have been reported at lower storage temperatures (Baker et al, 1986; Brody, 1989; Gill and Tan, 1979; Gill et al, 1990). This is due to high solubility of CO₂ into fluids at refrigeration temperatures. Solubility of CO₂ into product fluids has been thought to cause a decrease in pH which would inhibit microbial growth (King and Nagel, 1967). The pH changes reported seem to have no affect on microbial growth in MAP products (Seman et al,

1988; Wabeck et al, 1968). A shift of less than 0.9 pH units has been reported by Hintlian and Hotchkiss (1986). Huffman et al, (1975) found a change of 0.1 pH units over a 27 day storage period. It appears that inhibition of microbial growth is not due to lowering of pH.

b) The inhibitory effect of CO₂ on bacteria has also been attributed to its interaction which causes a disruption in the ion transport through the bacterial cell membrane (Sears and Eisenberg, 1961; Castelli et al, 1969; Enfors and Molin, 1980).

c) Another theory under consideration is the inhibition of enzymes involved in bacterial metabolic activity. King and Nagel (1975) reported inhibition of isocitrate dehydrogenase and malate dehydrogenase activity of Pseudomonas aeruginosa, caused by CO₂. Oxaloacetate decarboxylase in Rhizopus nigricans was affected by CO₂ in studies by Foster and Davis (1949).

Whatever the mechanism(s) involved in CO₂ inhibition of microorganisms, the result is seen in an extension in the lag phase of bacteria growth (Gill et al, 1990) and an increase in the generation time (Anderson et al, 1985; Dixon and Kell, 1989).

2.3.3.1. Effect of CO₂ on Microorganisms

Many meat products have been used to study the effects

of CO₂ on their microflora and shelf-life. Most of the results indicate that CO₂ is effective in suppressing microbial growth, but the optimal level of CO₂ is still under debate.

Use of high elevations of CO₂ in modified atmosphere packages causes the predominantly Gram-negative microflora to shift to a predominantly Gram-positive microflora during storage (Silliker and Wolfe, 1980; Bailey et al, 1979; Baker et al, 1985). Psychrotrophic Gram-negative bacteria are those which produce off-odors and off-flavors in raw poultry, pseudomonads are one such group of bacteria. Gill and Tan (1980) reported respiration and growth inhibition of Pseudomonas, Altermonas putrefaciens and Yersinia enterocolitica due to CO₂. Maximum inhibition was reached at relatively low concentrations of CO₂. This inhibitory pattern was reportedly due to the effect of CO₂ on enzymes involved in oxidative metabolism. This contradicts information on such organisms as Acinetobacter (Gill and Tan, 1980), Pseudomonas aeruginosa (King and Nagel, 1975), Pseudomonas fragi, Bacillus cereus and Streptococcus cremoris (Enfors and Molin, 1980) which are inhibited proportional to increased concentrations of CO₂. King and Nagel (1975) reported this was a result of mass action of CO₂ upon enzymatic decarboxylation, specifically affecting a few enzymes.

Elevated CO₂ levels in modified atmosphere packages have been known to inhibit growth of Salmonella which prefers an oxidative metabolism (Hintlian and Hotchkiss, 1987). Silliker and Wolfe (1980) believe elevated CO₂ levels will provide a protective effect on meat products subjected to moderate temperature abuse. This was demonstrated by Baker et al, (1986), at 2°, 7°, and 13°C a 80% CO₂ atmosphere reduced growth of Salmonella typhimurium. The most effective storage temperature was 2°C. This is due to the high solubility of CO₂ into fluids at refrigeration temperatures. For this reason, MAP will not eliminate or reduce the need for proper refrigeration. It will only extend shelf-life and reduce product loss due to spoilage.

Anaerobic bacteria are capable of growing in the absence of O₂ or in very low O₂ levels. A concern is that some pathogenic, anaerobic bacteria will find growth favorable in packages with elevated CO₂ levels. Hotchkiss (1989) has recommended modified atmospheres of no more than 67% CO₂ and at least 5-10% O₂ as a safety factor. O₂ is lethal to anaerobic bacteria because of the production of toxic substances. These toxic substances can include hydrogen peroxide and other organic peroxides and superoxide radicals which form when flavins, quinones, and other electron carriers are oxidized. Most aerobic bacteria produce superoxide dismutase which destroys superoxide

radicals, producing oxygen and hydrogen peroxide. Also, aerobes produce catalase and peroxidases which split the peroxide substances to form oxygen and water (Freeman, 1985). However, Silliker and Wolfe (1980) reported that little evidence is available to support a conclusion that elevated CO₂ levels increase the hazards of botulism in fresh meats. These authors suggest that elevated CO₂ atmospheres do not increase the incidence of botulism in fresh meat and poultry. However, the available information does not suggest a reduction of this hazard due to elevated CO₂ levels.

2.3.3.2. Effect of CO₂ on Meat Color

The color imparted by meat is primarily due to myoglobin present in muscle tissue after slaughter. Myoglobin is a protein consisting of a single polypeptide chain attached to a heme group. In the center of the heme group is a single iron atom. Myoglobin serves as a storage site for O₂ for use by muscle tissue.

Myoglobin can exist in several forms, the first is the reduced form called deoxymyoglobin. Deoxymyoglobin is a purplish red color. This color is commonly seen when the heme group is not bound to any molecules other than H₂O, such as when O₂ is excluded from contact with fresh meat. Deoxymyoglobin can readily combine with O₂ to produce

oxymyoglobin. Oxymyoglobin is a bright red pigment which is a result of O₂ binding with the heme group, a minimum of 5% O₂ is needed to oxygenate deoxymyoglobin (Brody, 1989).

Meat is considered fresh and safe by consumers when in the oxymyoglobin state. When meat is exposed to O₂, the O₂ will continually associate and dissociate with the heme present in the muscle. When this occurs, the myoglobin will become oxidized and will lose its ability to bind with O₂.

Oxidation of meat results in metmyoglobin formation, an unacceptable brown pigment.

The effect of high levels of CO₂ on meat color has been a concern. Consumers are familiar with the bright red color associated with oxygenated myoglobin. In the absence of O₂, the myoglobin is reduced and unoxygenated, causing the pigment to become darker. Baker et al, (1985) observed a decrease in a+ (redness) values and an increase in L (lightness) values when poultry was packaged in high levels of CO₂ compared to air packaged poultry. Use of at least 10% O₂ is recommended to maintain oxymyoglobin levels and to give the bright red color consumers expect (Schweers, 1991; Hotchkiss and Galloway, 1989). Even though only 5% O₂ is necessary for oxymyoglobin formation, levels of 10% and above provide conditions for the bright red oxymyoglobin color.

2.4 Advantages and Disadvantages of MAP

Potential advantages to using MAP technology include: potential shelf-life increases of 50-400%; reduced economic loss due to spoilage; increased distribution area; and a higher quality product provided to the consumer. The disadvantages might include: added cost; requirements for strict temperature control during storage; development of different gas formulations for each product type; and requirement of special equipment and personnel training (Farber, 1991).

3. Naturally Occurring Antioxidants

Exclusion of O₂ may not be the only method to prevent oxidation. Stability of many food items against spoilage due to rancidity can be affected by naturally occurring substances having antioxidant activity. Ascorbic acid, which is found in many fruits and vegetables, helps increase the shelf-life of food products by reducing free radicals. Antioxidant properties are also associated with soybean and oat products. Some spices have exhibited these properties as well. Antioxidant properties of natural spices have been known for many years (Chipault, et al., 1969).

3.1 Rosemary Oleoresin

Rosemary oleoresin is an extract of rosemary leaves,

officially referred to as Rosemarinus officinalis L. Many extracts may be unsuitable for addition to food products due to strong odors and bitter taste. For this reason, some oleoresin producers remove the chlorophyll and camphor from these extracts (Shuler, 1990). The powder form of the extract is dissolved in vegetable oil to aid in application. In 1952, Chipault, et al. reported on antioxidant properties of 32 spices. Ground samples, and petroleum ether-soluble and alcohol-soluble fractions of rosemary demonstrated very pronounced antioxidant activity.

The antioxidant substances in rosemary are primarily phenolic compounds, which serve to terminate free radical chains in lipid oxidation. The main antioxidant compound in rosemary is carnosic acid which donates a hydrogen to the free radical, during the propagation phase of oxidation, which inhibits the occurrence of the terminal phase (Gordon, 1990). Rosemary has demonstrated potent antioxidant effects in animal fats (Schuler, 1990)

Rosemary oleoresin at 20 ppm was tested (Barbut et al, 1985) against a commercial blend of BHA/BHT/Citric Acid at 200 ppm. TBA values indicate no differences between the two treatments. Rosemary samples also compared favorably with the commercial mixture when assessed by sensory evaluations. McNeill and Kakuda (1988) tested the ability of rosemary extract to prolong the oxidative shelf-life of mechanically

separated chicken meat during frozen storage. Rosemary had a beneficial effect on the oxidative stability of meat when used at levels of 0.1, 0.2, and 0.3%. Rates of malonaldehyde formation were significantly lower in rosemary samples than control samples.

III. MATERIAL AND METHODS

Chilled, fresh, boneless turkey thigh meat, 48 h post-slaughter, was obtained from Wampler-Longacre Turkey (Hinton, VA). The meat was stored in a 1°C cooler until it was packaged, 72 h post-slaughter. Processing of the meat was conducted in a 1°C cooler. Two fat levels were tested, 3.5% and 7%.

1. Preparation and Packaging of Ground Meat

Meat ground without trimming of the fat was found to have 7% fat. Lower fat levels, 3.5%, were obtained by trimming the meat of all possible excess fat prior to grinding. Meat grinding was conducted using a Model 4532 Hobart (Troy, OH) grinder with a 3/16" plate. Klenzade (Division of Ecolab, Inc., St. Paul, MN) XY-12 liquid sanitizer was used at 200 ppm, in accordance with label instructions, to sanitize the grinder. Before use, the grinder was rinsed of sanitizer with tap water.

Ground meat was weighed out into 100 g portions and placed into 5.5 x 3.75 x 1.5 inch crystallized polyethylene (CPET) trays provided by Fisher Packaging Company (Ft. Wayne, IN). Trays of meat were then placed into transparent Cryovac (W.R. Grace & Co., Cryovac Division, Duncan, SC) B-540 coextruded plastic bags measuring 7.5 x 14.5 inches. Composition of the bags was 0.6 mil biaxially oriented nylon

and 3.0 mil polyethylene coated with polyvinylidene chloride (PVDC). The bags had an O₂ transmission rate of 3-6 cc @ 40° F.(m², 24 hrs., atm @ 40°F, 0% RH).

A 28-day shelf-life study of each fat level was conducted with four atmospheres: air as a control, 80% O₂/20% CO₂, 60% O₂/40% CO₂, and 100% CO₂. Gas mixtures were regulated with a Smith Proportional Gas Blender, Model 299-037F (Waterfront, SD). Packages were evacuated and then back-flushed with the appropriate gas composition. A Multivac (Wolfertschwenden, W. Germany) A300/52 package sealer was used. Sealed packages were stored in a 1°C cooler.

During this study, samples were pulled from the cooler at 0, 4, 7, 11, 14, 21, 25, and 28 days for a series of tests which included: gas composition, pH, microbiological analysis, color, TBA, and sensory characteristics. All shelf-life tests were conducted with triplicate replication.

2. Analysis of Headspace Gas Composition

Each package pulled on test days were tested to verify headspace gas. Gas composition was determined with a Fisher-Hamilton (Pittsburgh, PA) Gas Partitioner Model 29, and a Hewlett-Packard HP 3396A Integrator (Avondale, PA). The integrator was standardized with a standard gas mixture

of 24.67% CO₂, 24.89% O₂ and 50.44% N₂. Calculation of gas composition by the integrator was on a percent basis after standardization. A 14 gauge, 4" laboratory cannula was used to remove 0.5 ml of gas from the test package and injected into the gas partitioner. Sterile syringes were used for each package tested.

3. Microbiological Testing

Three series of microbiological tests were conducted for each sample during the test days; modified psychrotrophic bacteria count (mPBC), anaerobic plate counts, and lactic acid bacteria enumeration. Each microbiological test was conducted using 11 g of ground turkey sample, diluted with 99 ml of a 0.1% Bacto Peptone (DIFCO Laboratories, Detroit, MI) solution and blended in a stomacher for two min.

3.1. Psychrotrophic Bacteria Enumeration

mPBC were determined using BBL Standard Methods agar (Becton Dickinson Laboratories, Cockeysville, MD). Plates were incubated at 21°C for 25 h after which the number of colony forming units (cfu) per gram were calculated (Oliveria and Parmelee, 1976).

3.2. Anaerobic Bacteria Enumeration

Anaerobic plate counts, using Bacto Liver Veal Agar (DIFCO Laboratories, Detroit, MI) were conducted to track the growth of anaerobes such as Clostridia and other facultative anaerobes. Plates were incubated in anaerobe jars with BBL GasPak Plus Anaerobic System Envelope with catalyst (Becton Dickinson, Cockeysville, MD) at 35°C for 24 h, at which time cfu per gram were determined (Anonymous, 1984).

3.3. Lactic Acid Bacteria Enumeration

Growth of lactic acid bacteria was monitored using MRS agar. Bacto Lactobacilli MRS Broth (DIFCO Laboratories, Detroit, MI) and 1.5% Fisher Scientific Agar (Fair Lawn, NJ) plates were incubated at 35°C for 48 h. CfU per gram were then calculated (Richardson, 1985).

4. Chemical and Physical Analysis of Ground Turkey Meat

Chemical and physical analysis of ground turkey thigh meat were conducted to determine the characteristics of the meat, and possible changes during the course of the 28-day storage period.

4.1. Fat Level Determination

Twenty-two and one-half grams of ground turkey, 80 g of plaster of paris, and 120 ml of tetrachloroethylene were

homogenized in the Foss-Let Homogenizer (Foss Electric Co., Denmark). This homogenate was filtered using Whatman 50 filter paper and the extract tested in the fat analyzer.

4.2. pH Measurement

Effects of each atmosphere upon the pH of the turkey meat was determined. Ten gram samples of meat were blended with 100 ml of distilled water for one minute (Ockerman, 1981) in a Model S10-400 Stomacher (Tekmar Company, Cincinnati, OH). The homogenate was tested with an Accumet pH meter, Model 925, (Fisher Scientific, Fair Lawn, NJ). The meter was standardized on each test day using standard buffer solutions of pH 7 and pH 4.

4.3. Color Evaluation

Color differences due to gas composition were evaluated over the 28 day test period. A Minolta Color Meter, Model CR-200 (Osaka, Japan), was used to obtain CIE L*, a*, and b* values. Three readings were taken from each sample and an average calculated. The 3.5% fat level samples were tested for color immediately upon opening of the package. Samples with 7% fat levels were tested immediately after removal of microbial test samples.

4.4. TBA Analysis For Rancidity

TBA values for ground turkey thigh meat, for each treatment, were determined by the distillation method described by Tarladgis et al. (1960) and modified by Ockerman (1981). A modified TBA test as described by Rhee (1978) was followed, whereby a 5% antioxidant solution of propyl-galate (PG) and ethylene diamine tetracetic acid (EDTA) (SIGMA Chemical Co., St. Louis, MO) was added during the preparation of the samples. Procedures for sample preparation, assay, standard curve preparation, recent recovery, and calculation of TBA values, as developed by Tarladgis, et al. (1960) and Ockerman (1981) are described as follows.

4.4.1. Preparation of Samples

Ten gram samples of turkey from each atmosphere and fat level were mixed with 50 ml of distilled water and 5 ml of antioxidant solution for two minutes. The homogenate was transferred to a 500 ml Kjeldahl flask and a solution of 47.5 ml distilled water and 2.5 ml of 4 N hydrochloric acid (HCL) added. This mixture was distilled on a high temperature heating mantle for 15 min. Five ml of each distillate was transferred to a test tube for TBA assay.

4.4.2. TBA Assay

Five ml of a 0.02 M TBA (Sigma, St. Louis, MO) solution

was added to each sample test tube. Test tubes were loosely capped and placed in a boiling water bath for 35 min, then cooled in tap water for ten min. Absorbance of each sample was measured at 530 nm against a blank (5 ml distilled water and 5 ml TBA solution) using a Model 21D Spectrophotometer (Milton Roy, WA).

4.4.3. Standard Curve Preparation

A standard curve was prepared using a 10^{-3} M stock solution of tetraethoxypropane (TEP) (Sigma, St. Louis MO). This solution was pipetted in amounts of 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9 ml into 50 ml volumetric flasks and diluted to 50 ml with distilled water. Five ml of each solution was placed into test tubes for TBA assay. Absorbance was plotted versus concentration and a slope of the curve was determined using regression analysis. A standard curve was determined for each replication of the test.

4.4.4. Percent Recovery Determination

Percent recovery was determined using a 10^{-4} M stock solution of TEP. One, two, three, four, and five ml of this stock solution were placed into separate 100 ml volumetric flasks. Two and a half ml of 4 N hydrochloric acid solution were placed into each flask, and all solutions

made up to a 100 ml volume with distilled water. These solutions were distilled, and five ml of each distillate were transferred into test tubes for TBA assay.

4.4.5. Calculation of TBA Values

TBA values were determined by multiplying the absorbance reading from test samples by a constant K. The K constant is calculated from the standard curve and the known dilutions:

$$K = \frac{\text{concentration of malonaldehyde in moles/distillate}}{\text{OD}} \times \frac{5 \text{ ml of}}{\text{M.W. of malonaldehyde}} \times \frac{10^7}{\text{sample wt}} \times \frac{100}{\% \text{ recovery}}$$

5. Sensory Analysis of Ground Turkey Meat

Effects of modified atmosphere conditions were evaluated for organoleptic properties by an experienced sensory panel. The panel consisted of at least six panelists for each test day. The parameters for evaluation included rancidity and over-all flavor.

Samples were prepared by forming the ground turkey into patties in a 3 x 4.25 x 0.31 inch mold. Patties were cooked in Presto electric skillets (National Presto Ind. Inc., Eau Claire, WI) at a temperature setting of 300°F until an internal temperature of 170°F was obtained (approximately 6 min). Six 1 x 1 inch samples were cut from each patty for

evaluation by panelists. Samples were cooked and presented simultaneously with cooked, reference samples. Fresh, market reference samples were not used due to the presence of rosemary oleoresin, therefore, ground turkey to be used as a reference was vacuum packaged in 300 g portions and frozen at -16°F on day zero. One portion was removed from the freezer and thawed for each test day.

The method of sensory evaluation used was quantitative descriptive analysis (QDA) with scaling (Larmond, 1977; Stone and Sidel, 1985). Training was conducted during six sessions to acquaint panelists with common off-flavors associated with ground turkey. Descriptors at the anchors of the six inch scaling line were "Not Rancid" and "Very Rancid" for rancidity evaluation. "Good Over-all Taste" and "Poor over-all taste" were used in evaluating over-all acceptability (See Appendix).

Panelists were asked to evaluate the samples for rancidity and over-all taste by placing a vertical mark on the six inch scale. Distance from the left end of the line to the vertical mark was measured for statistical analysis.

6. Rosemary Oleoresin Antioxidant

The antioxidant properties of rosemary oleoresin (KALSEC, Inc., Kalamazoo, MI) were tested in fresh, ground turkey thigh meat. Oleoresin was added to the meat prior to

grinding at 0.1% by weight. Samples with rosemary oleoresin were packaged in a 80% O₂/20% CO₂ atmosphere and tested over a 28 day period as indicated above. Sensory analysis was not conducted with rosemary samples because its antioxidant properties were of primary concern, as tested by TBA analysis.

7. Statistical Analysis

All data was analyzed using Statistical Analysis Systems (SAS Institute, Inc., Cary, NC) and a split-plot experimental design. Sensory analysis was evaluated using split-plot analysis and Dunnett's experimental design. The level of significance for all analysis was 0.05.

IV. RESULTS AND DISCUSSION

1. Headspace Gas Analysis

Prior to chemical, microbial and sensory analysis, headspace gas composition was determined to monitor changes during storage (Figures 1-3). The levels of CO₂ within the 100% CO₂ treatment remained consistent throughout the 28-day test period. The gas mixture in the 80% O₂/20% CO₂ and 60% O₂/40% CO₂ treatments changed slightly in their composition. Aerobic bacteria will not grow above 50% O₂ while facultative anaerobes which are capable of growth with or without O₂, are capable of growth under these conditions. The air control showed a steady increase in CO₂ levels and a decrease in O₂ levels during the first 21 days. This was due to the growth and respiration of aerobic bacteria which grow well at 20% O₂. The respired CO₂ collects in the package, inhibiting the aerobic bacteria. Changes in headspace composition were expected to occur.

2. Fat Level Determination

Fat level determination indicated that the trimmed meat contained 3.5% fat ± 0.6643 . The untrimmed meat contained 7% fat ± 0.7174 . Statistical analysis demonstrated that tests with the 3% and 7% fat levels were not significantly different ($P > 0.05$) in all treatments, except b* color values.

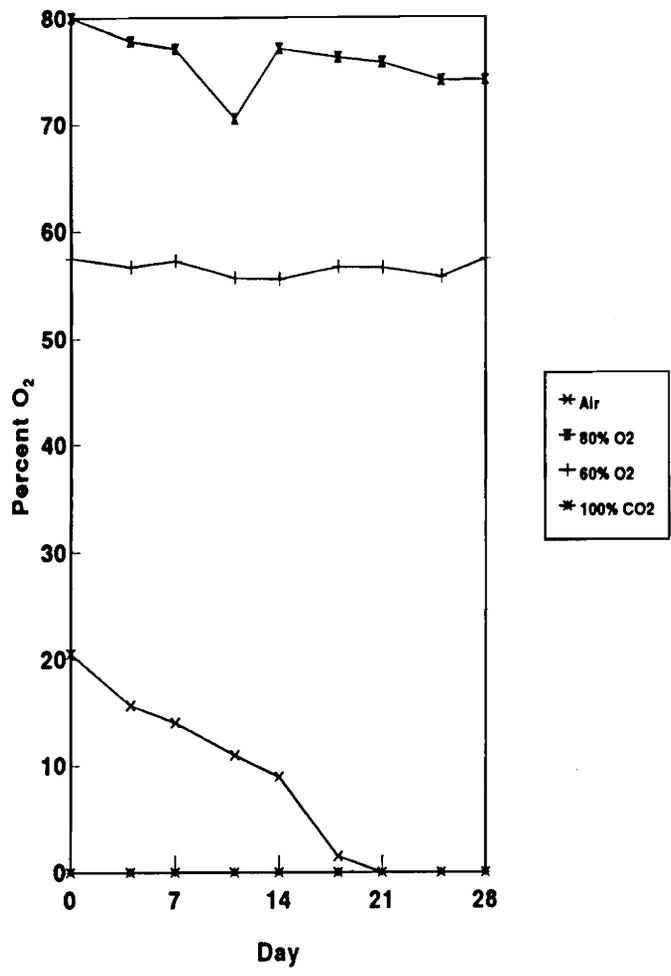


Figure 1: Headspace Oxygen Levels of MAP Ground Turkey Thigh Meat Stored at 1°C.

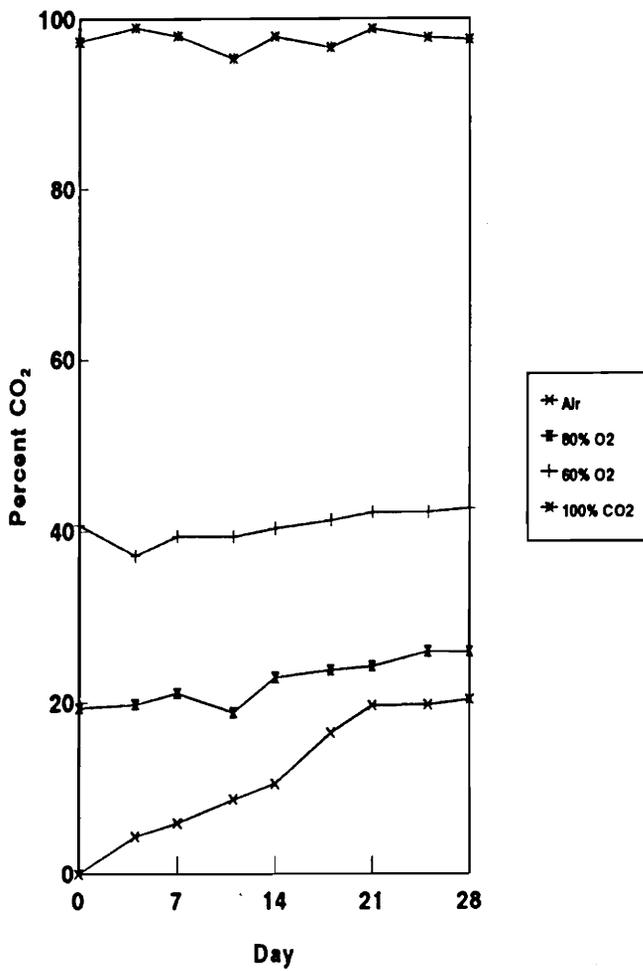


Figure 2: Headspace Carbon Dioxide Levels of MAP Ground Turkey Thigh Meat Stored at 1°C.

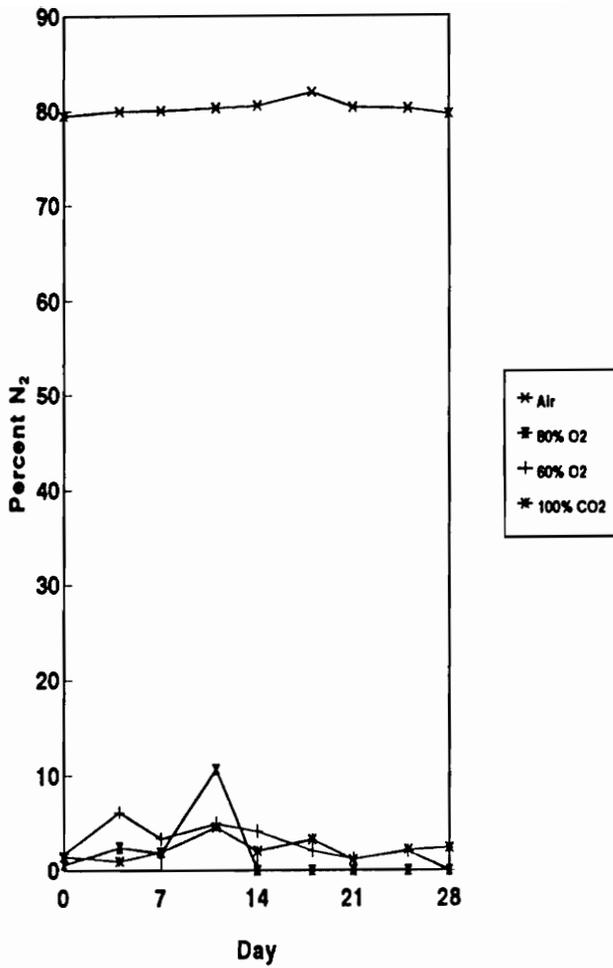


Figure 3: Headspace Nitrogen Levels of MAP Ground Turkey Thigh Meat Stored at 1°C.

3. pH Measurement Analysis

Results (Figure 4) indicate that the pH of all treatments was significantly different from the air control ($P < 0.05$). The pH for the air treatment changed by only 0.4 units during storage. The pH steadily increased until day 21, when O_2 was depleted. This increase in pH indicates residual ammonia byproducts from microbial growth. The pH of the other treatments fluctuated during the 28 days, but only varied by 0.1 units from initial pH of 6.2. Hotchkiss et al. (1985) indicated that pH levels of chicken quarters (breast and leg) changed by less than 0.9 units and had no clear effect due to CO_2 . A change of only 0.10 pH units was found in ground chicken by Baker et al. (1985), also indicating that changes in pH does not contribute to extended shelf-life in regard to elevated CO_2 treatments.

4. Microbial Analyses

Microbial testing included lactic acid, mPBC and anaerobic bacterial enumeration (Figures 5-7). Results were consistent for all three tests, with control samples having significantly ($P < 0.05$) more growth than MAP treatments. Following the control, the 80% O_2 /20% CO_2 treatment allowed the quickest bacterial growth while the 100% CO_2 treatment was most inhibitory to bacterial growth.

Our results agree with others who indicate that

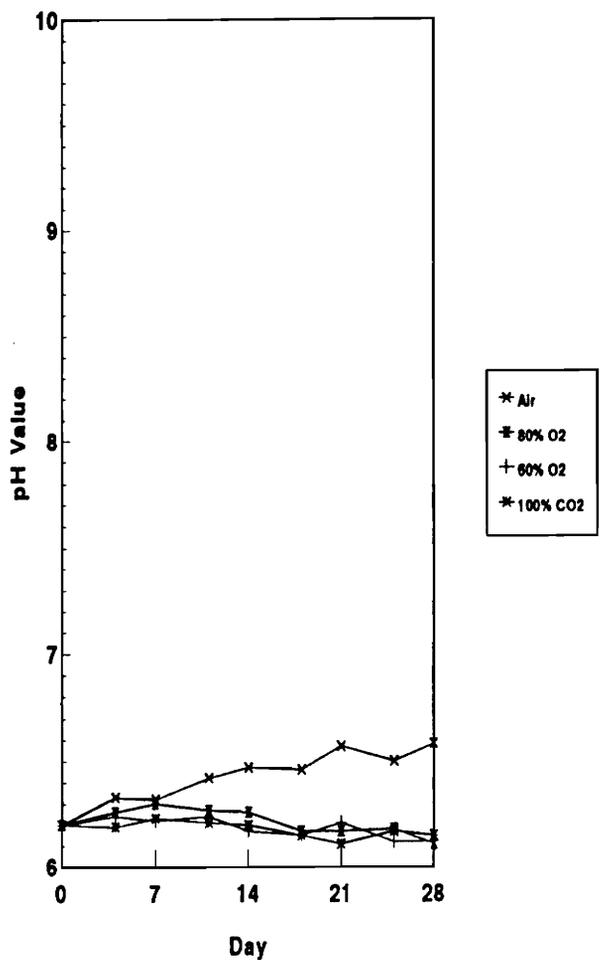


Figure 4: pH Values of MAP Ground Turkey Thigh Meat Stored at 1°C.

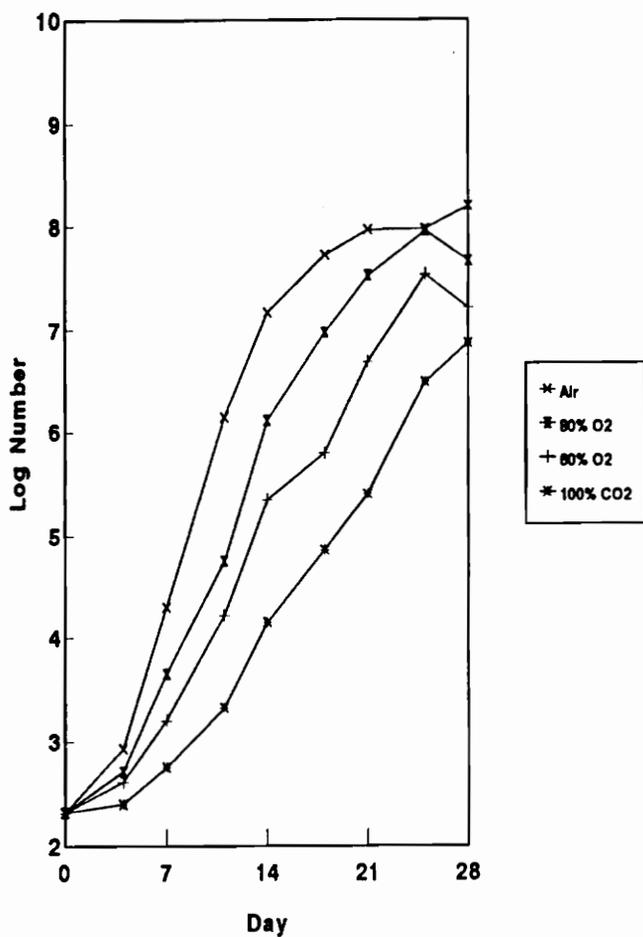


Figure 5: Lactic Acid Bacteria Results of MAP Ground Turkey Thigh Meat Stored at 1°C.

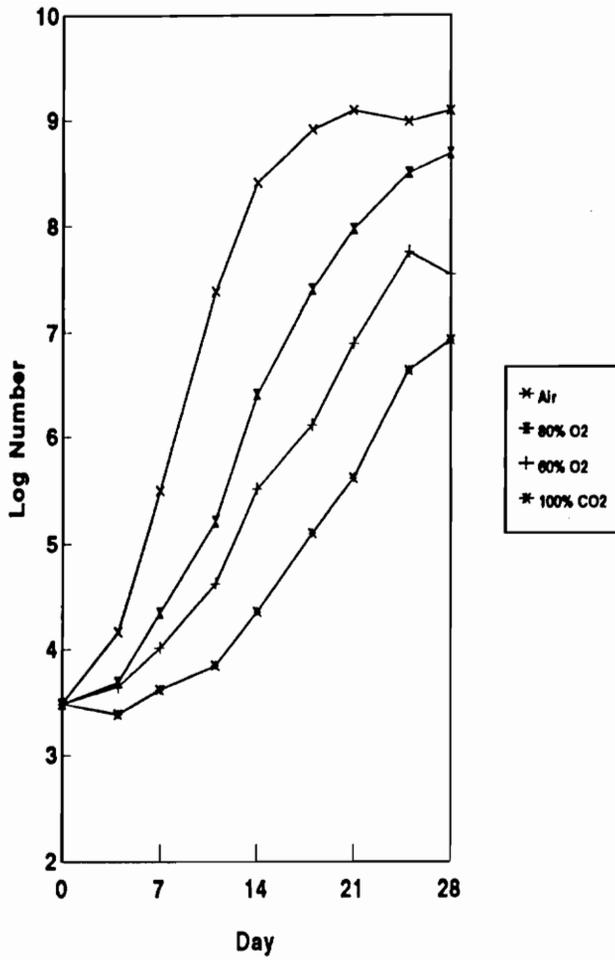


Figure 6: Psychrotrophic Bacteria Results of MAP Ground Turkey Thigh Meat Stored at 1°C.

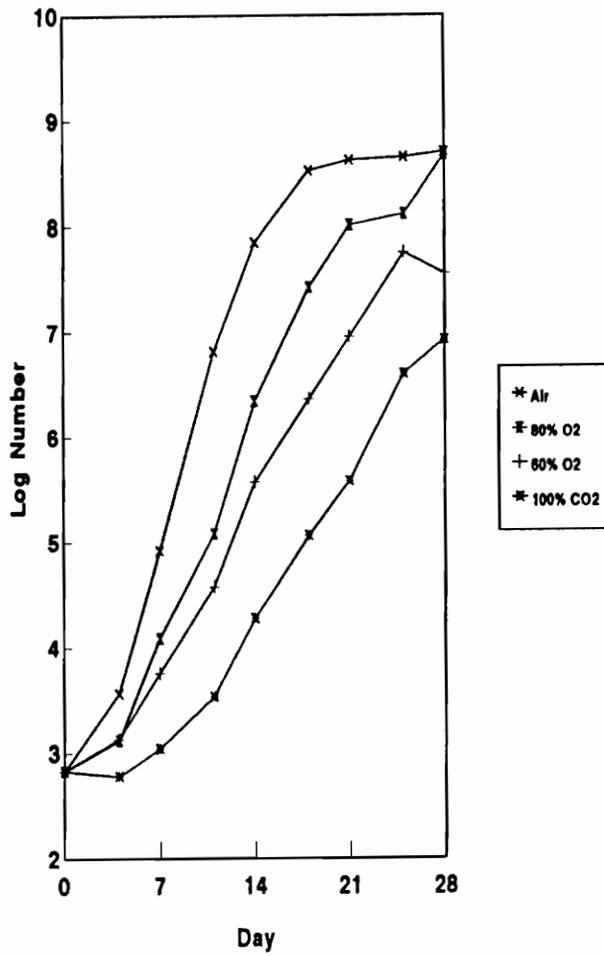


Figure 7: Anaerobic Bacteria Results of MAP Ground Turkey Thigh Meat Stored at 1°C.

elevated CO₂ levels cause a shift from a gram-negative microflora to gram-positive (Silliker and Wolfe, 1980; Bailey et al., 1979; Baker et al., 1985). By day 11, the majority of bacteria in our treatment samples were lactic acid bacteria. These bacteria are primarily facultative anaerobes which are capable of growth in conditions not conducive to aerobic growth; elevated CO₂ levels and/or elevated O₂ levels.

This study indicated that inhibition of microorganisms increased with increasing CO₂ levels; as was found by King and Nagel (1975) and Enfors and Molin (1980). This contradicts Gill and Tan (1980) who found maximum inhibition at relatively low levels of CO₂. Gill and Tan (1980) tested bacteria which are strict aerobes while the others tested facultative anaerobic bacteria.

The lag phase of the 100% CO₂ treatment was extended in comparison with other treatments and control. Approximately a seven day lag phase was detected with the 100% CO₂ treatment, a maximum of four days for the high O₂ treatments.

A slower exponential phase was reflected in the 100% CO₂ samples, from day 7 to day 28. The high O₂ treatments maintained growth during days 4 through 25. A lag phase was not present with the air control samples, growth of bacteria began on day 0 and continued through day 18.

The stationary phase of microbial growth was never reached in the 100% CO₂ packaged samples. This corresponds with results of the sensory panel, which demonstrated that the flavor of the 100% CO₂ treated samples were acceptable throughout the 28 day period. The high O₂ treatments were in the stationary phase for the last four days of this study. Day 14, the test day prior to onset of the stationary phase, was when the sensory panel chose to discontinue testing of high O₂ treatments due to rancid flavor. Air control samples exhibited the largest stationary phase, days 18 through 28, after having rapid bacteria growth during the first 18 days. Sensory panelists indicated the air control was no longer acceptable on day 18.

The lower fat level samples exhibited a lower microbial load initially, due to bacteria on the fat that was trimmed away. Overall, the fat level did not have an effect on microbial growth in the study.

5. Color Measurement Analysis

Color analysis was conducted to determine if any differences existed between treatments. A Minolta 200 colorimeter used for analysis produced output in CIE L* a* b* values. L* for lightness, a* for red (+60) and green (-60), and b* indicating yellow (+60) and blue (-60).

The L* values have been a key element in regard to previous studies. Baker et al. (1985) observed an increase in L values with elevated CO₂ levels, but the differences were small (<4.3 units). Our results indicate that L* values (Figure 8) were not significantly different (P>0.05) for any treatments. L* values were approximately 4 units higher for samples with higher fat levels. This was expected due to the lack of myoglobin in fat which contributed to the increased lightness.

The 100% CO₂ treatment initially lost red color, decreased a* values, (Figure 9) due to the change from oxymyoglobin to metmyoglobin. This change to a brown metmyoglobin was observed minutes after the meat was packaged demonstrating that metmyoglobin does not only occur when meat is old and oxidized. When very small quantities of O₂ are present as in a partial vacuum package, the pigment becomes oxidized and turns to a brown color (Judge et al., 1989). Even though we packaged the meat in 100% CO₂, oxygen incorporated into the meat due to grinding may not have been completely evacuated during packaging. After day 14, 100% CO₂ samples displayed a color reversion, increased a* values. From day 0 to 14, the O₂ in the meat was likely taken up by the bacteria for metabolism and used up by day 14. This would explain the shift in color to a more deoxymyoglobin pigment.

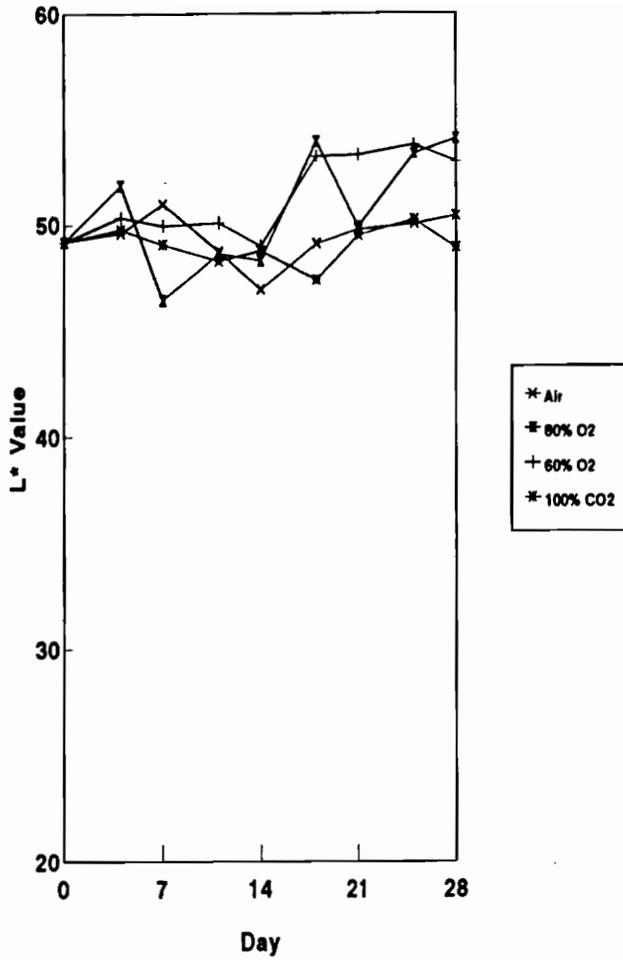


Figure 8: L* Color Values for MAP Ground Turkey Thigh Meat Stored at 1°C.

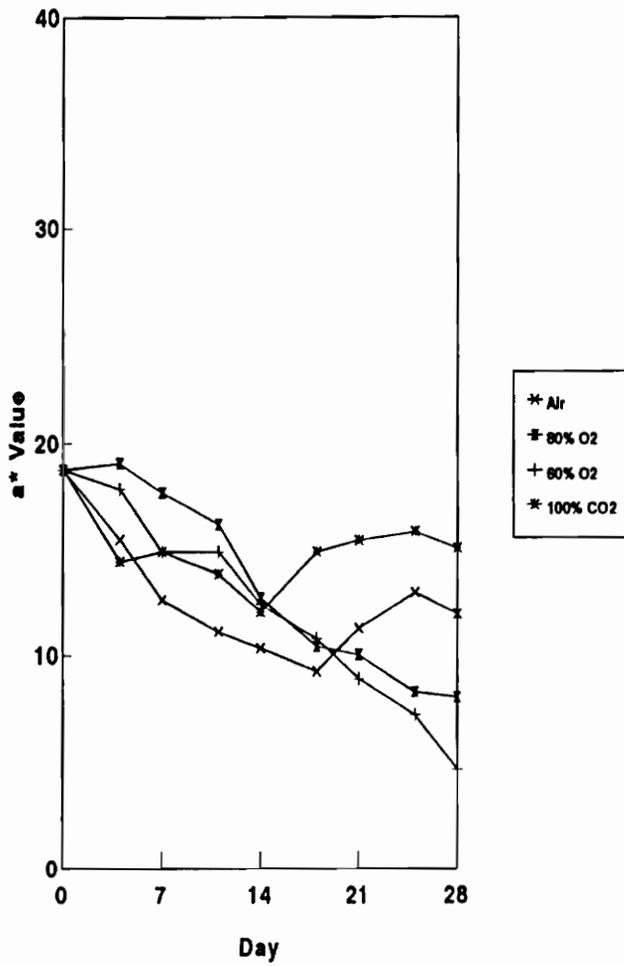


Figure 9: a* Color Values of MAP Ground Turkey Thigh Meat Stored at 1°C.

A shift in color was also seen in air-packaged samples after day 18. Color reversion has been reported in beef (Faustman et al., 1990) due to very high populations (ca. 10^8 CFU/g) of psychrotrophic bacteria. In our study, color reversion was evident in air-treated samples when psychrotrophic bacteria counts were 10^9 .

High O₂ treatments had a bright red oxymyoglobin initially, but they gradually lost their red pigment over the treatment period. This is best seen in the increased b* values (Figure 10) which indicate a higher degree of yellow color. The opposite effect occurred in the 100% CO₂ treatments where the b* value decreased, shifted toward the blue scale. This gave the meat a somewhat reddish-purple chroma, which may be considered acceptable to the consumer, but more testing needs to be conducted. Hotchkiss et al. (1985) tested elevated levels of CO₂ (60, 70 and 80%) for storage of raw chicken quarters. Sensory panelists scored the CO₂-packaged meat consistent with air control samples for color desirability, up to day 21. At days 28 and 35, the CO₂ treatments scored somewhat lower in sensory attributes but remained in the acceptable range.

The 60%O₂/40% CO₂, 7% fat level treatment, demonstrated a significant difference ($P < 0.05$) in b* value than that of the 3.5% fat level samples. The 7% fat level samples exhibited a greater b* (yellowness) value after day 14 than

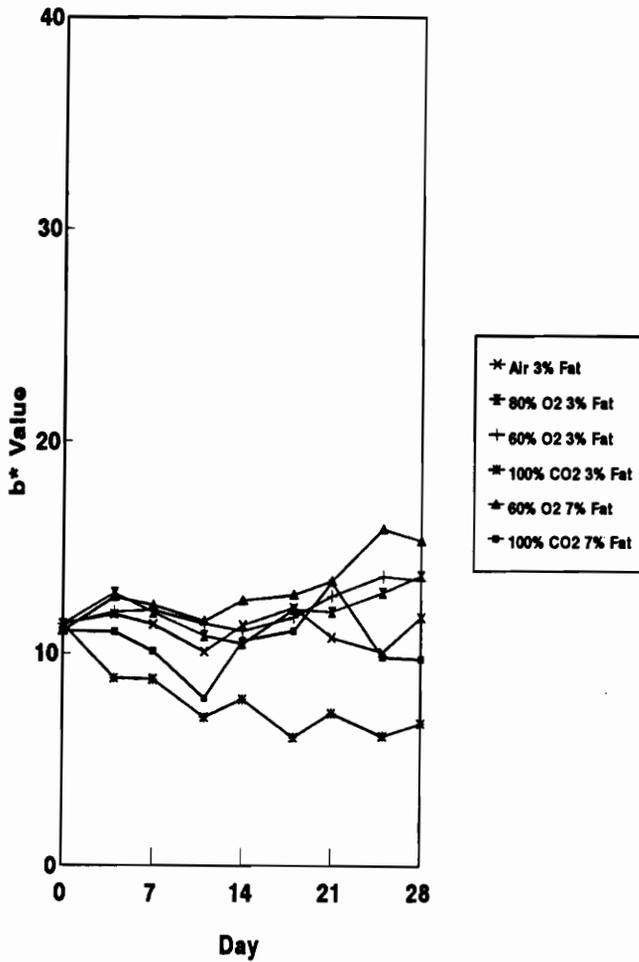


Figure 10: b* Color Values of MAP Ground Turkey Thigh Meat of 3% and 7% Fat Levels Stored at 1°C.

did the 3.5% fat level samples. The 100% CO₂ treatment, 7% fat level treatment also maintained higher b* values after day 11 than did 3.5% fat level samples.

6. TBA Analysis

Oxidative rancidity was quantified with TBA analysis. As can be seen in Figure 11, high O₂ treatments induced rancidity immediately after packaging, most significantly after day seven. This was expected since oxidation can occur when as little as 0.1% fatty acids and O₂ are present in foods (Inn, 1987). O₂ was ever present in the 80%O₂/20% CO₂ and 60% O₂/40%CO₂ packaged samples, allowing oxidation to occur throughout the test period. TBA values of one or higher are considered rancid (Ockerman, 1981). Both high O₂ treatments had TBA values of two or greater after day seven, reaching values near 16 by day 28. The air control maintained TBA values below five for the entire 28 day test period. The air treated samples maintained O₂ in the packages until day 21, allowing for oxidation. However, the O₂ levels were decreasing up to day 21, providing less O₂ to cause oxidation.

The 100% CO₂ treatment maintained the lowest TBA values (<4). The largest amount of rancidity in the 100% CO₂ packaged samples occurred between days 7 and 14. The oxidative rancidity that occurred may have been due to

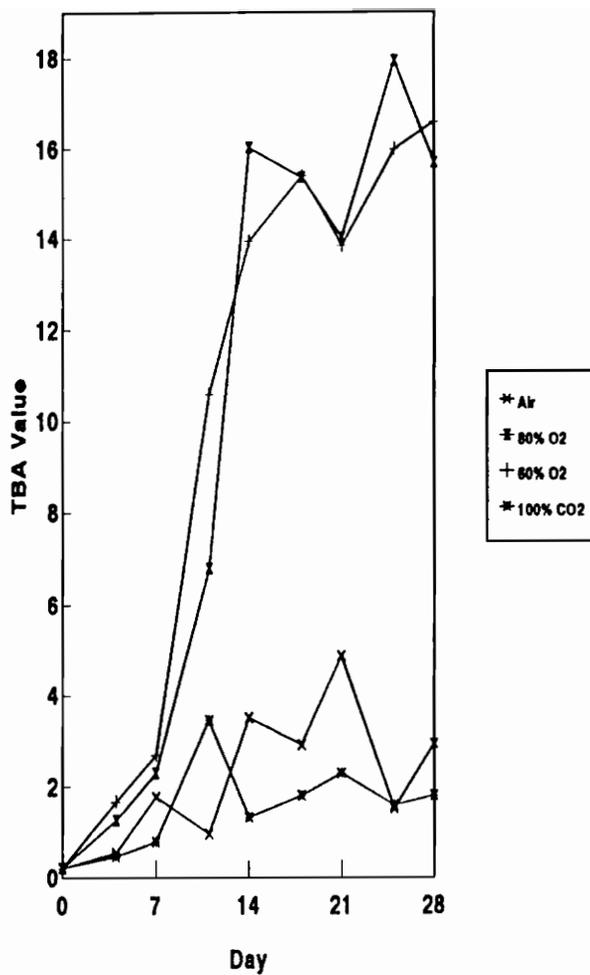


Figure 11: TBA Values of MAP Ground Turkey Thigh Meat Stored at 1°C.

small, undetected amounts of O₂ present in the meat due to grinding. Very little rancidity occurred in the 100% CO₂ samples after day 14.

Since the 7% fat level treatments have twice the fat of the 3.5% fat level, it would be expected that the higher fat level samples would oxidize and become rancid faster than the lower fat level samples. This did not hold true for any of the treatments tested.

7. Sensory Evaluation Analysis

Sensory analysis was conducted with a minimum of six panelists for each test day. Cooked samples were evaluated for rancidity and over-all flavor (Figures 12, 13). If over half the panelists agreed that the sample was poor quality it was removed from sensory evaluation. Panelists evaluated both high O₂ treatments as significantly more rancid and having poor over-all taste at day 7 when evaluated against a reference sample. On day 14, panelists determined the high O₂ treatment samples were of such poor quality that testing should be discontinued. The air control samples were eliminated after day 18. The 100% CO₂ treated samples and a hidden reference were tested for the entire 28 day period and were never considered poor in quality.

Sensory results indicated the hidden reference deteriorated over time. In a perfect sensory setting, this

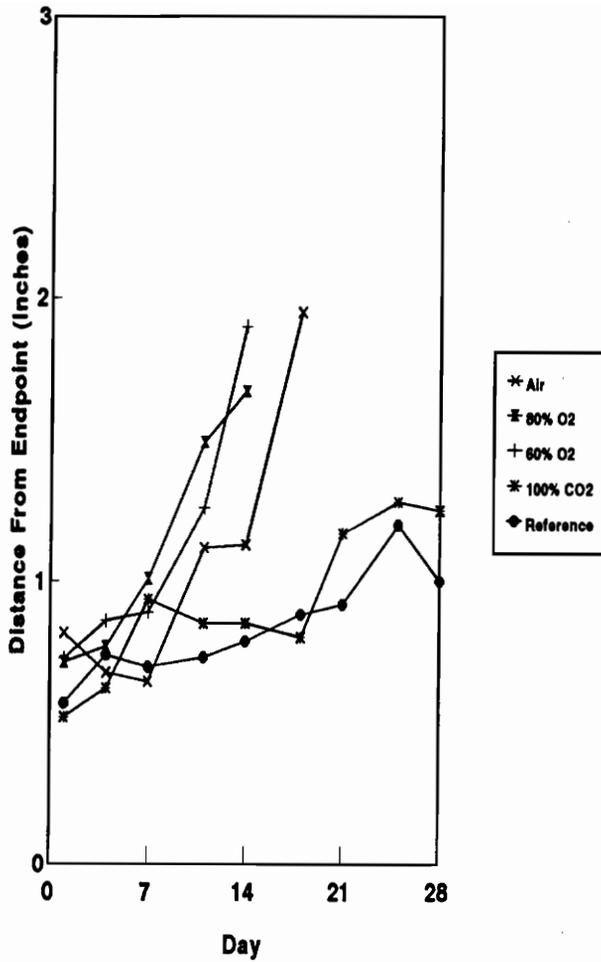


Figure 12: Sensory Evaluation of MAP Ground Turkey Thigh Meat Stored at 1°C. Reference Sample Vacuum Packaged on Day 0 and Stored at -27°C.

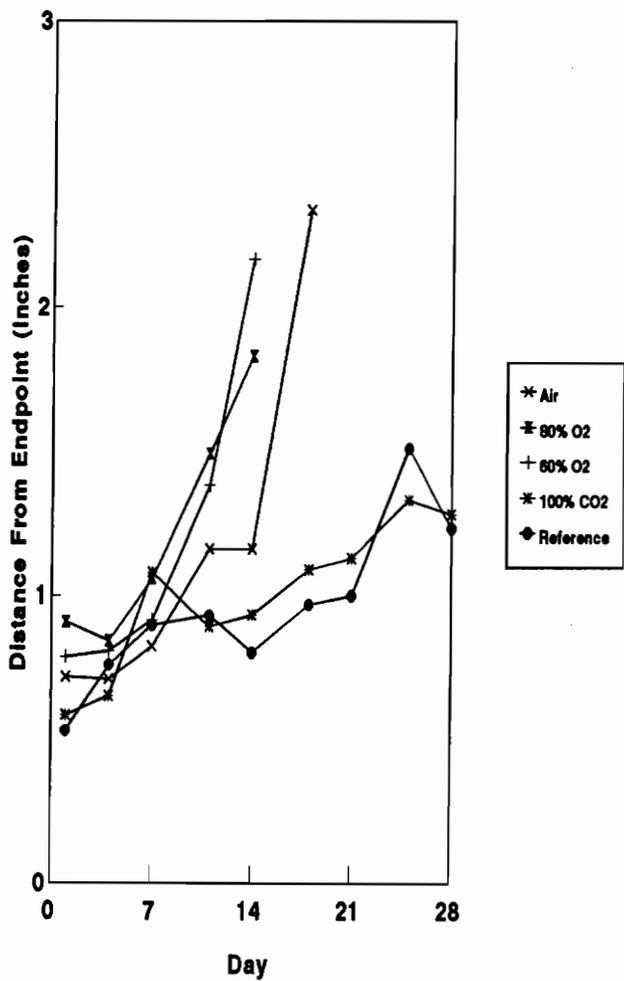


Figure 13: Sensory Evaluation of Over-all Flavor of MAP Ground Turkey Thigh Meat Stored at 1°C. Reference Sample Vacuum Packaged on Day 0 and Stored at -27°C.

would not occur. Even though meat for reference samples was vacuum packaged and stored at -16°F for the test period, TBA analysis indicated that rancidity occurred. TBA values for fresh meat at day 0 was 0.03 and 0.103 by day 28 for frozen reference samples. Sensory analysis was not conducted on meat with 7% fat.

8. Rosemary Oleoresin Results

Rosemary oleoresin was tested for antioxidant effects on ground turkey using 80% O_2 /20% CO_2 gas composition, this treatment was chosen because it was the worst case scenario in regard to rancidity in previous tests. Results were compared with those obtained with the 80% O_2 /20% CO_2 without rosemary.

8.1. Headspace Gas Analysis

Analyses of headspace gases in the rosemary treated samples (Figures 14-16) are consistent with untreated samples.

8.2 pH Measurement Analysis

In pH tests (Figure 17), the oleoresin did increase the pH of the meat, but by only 0.2 units. This small amount would not contribute to extended or decreased shelf-life of the meat.

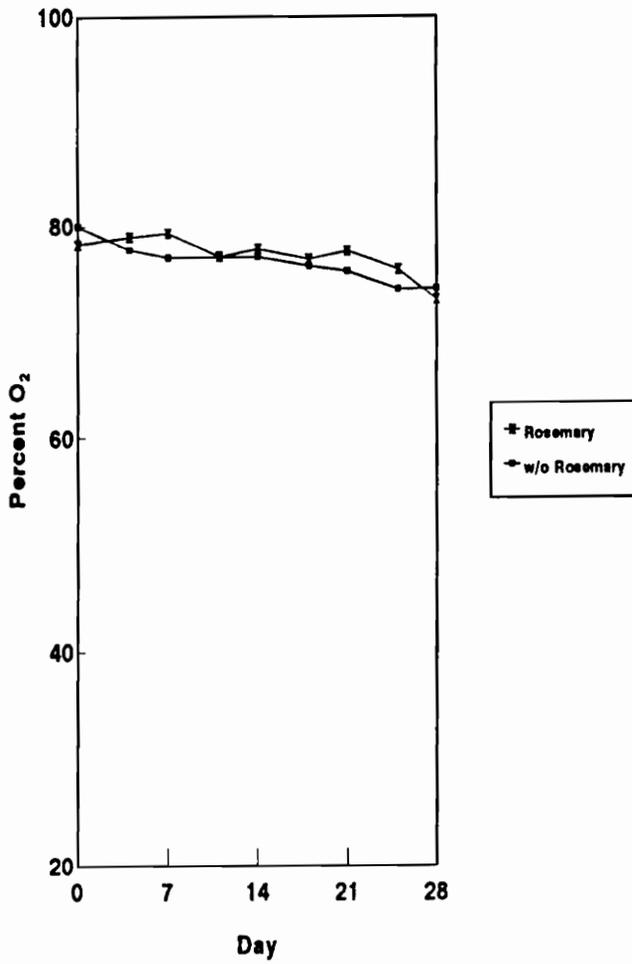


Figure 14: Headspace Oxygen Levels of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored at 1°C.

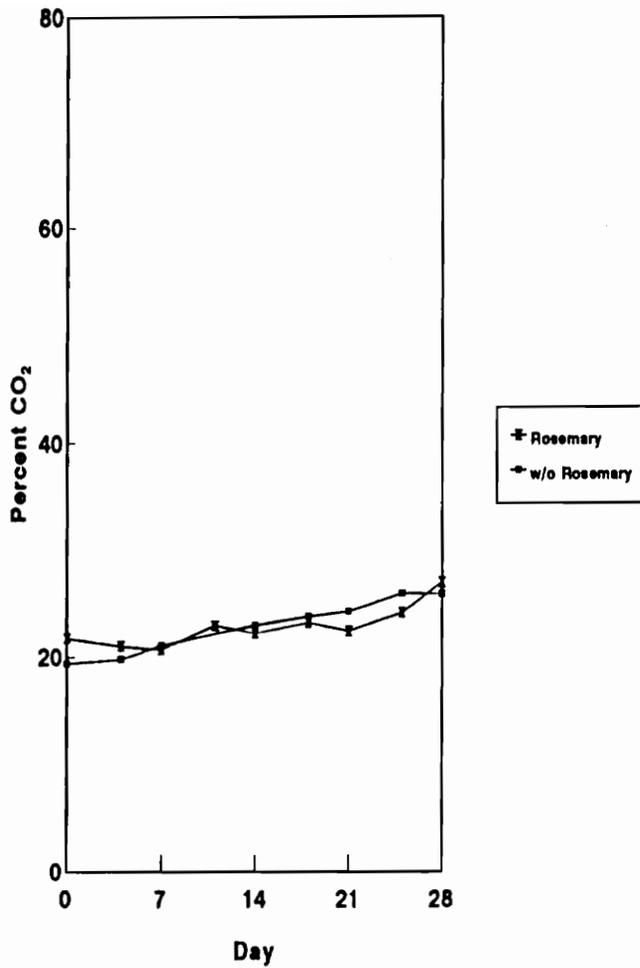


Figure 15: Headspace Carbon Dioxide Levels of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored at 1°C.

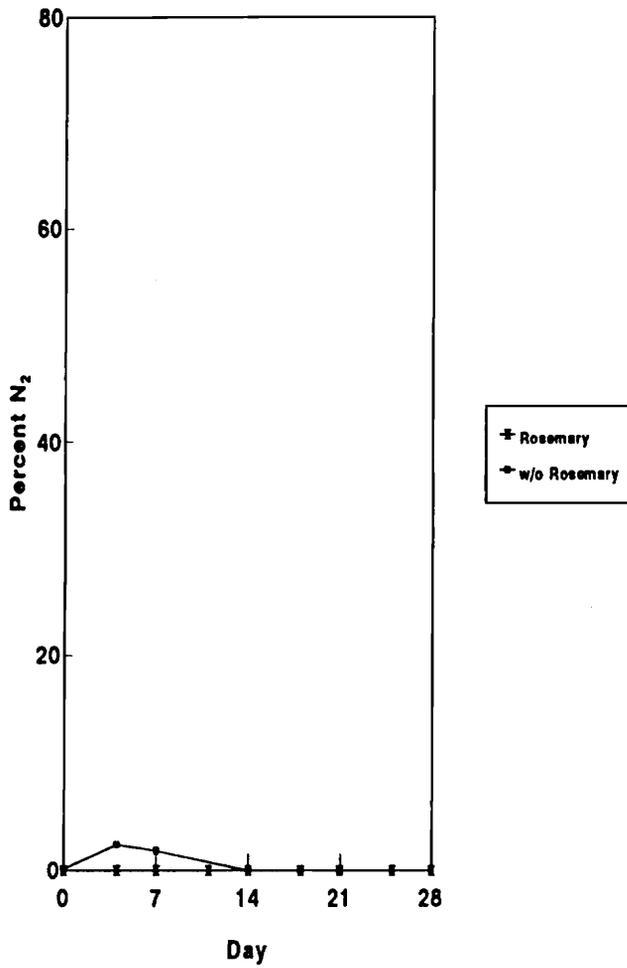


Figure 16: Headspace Nitrogen Levels of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored at 1°C.

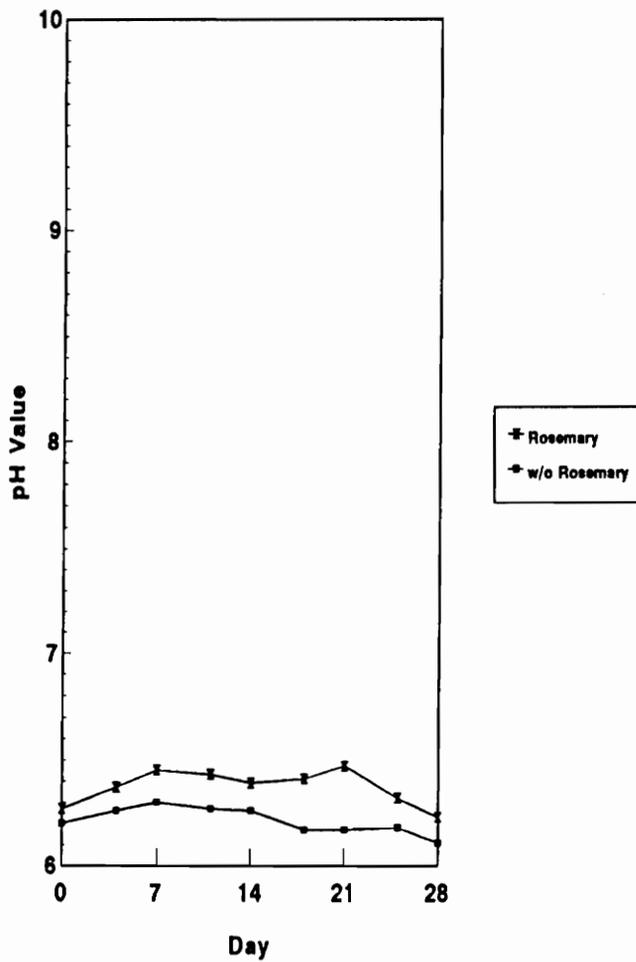


Figure 17: pH Values of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored at 1°C.

8.3 Microbiological Analysis

Microbial counts with the rosemary (Figures 18-20) were comparable to tests without rosemary. No apparent increase in microbial inhibition was obtained with rosemary oleoresin.

8.4 Color Measurement Analysis

Color analysis of the samples with oleoresin show some differences in the L* a* b* values when compared to untreated samples (Figures 21-23). The a* values for the rosemary treated samples were higher (more red) than untreated samples from day 11 through day 28 (Figure 22). It seems as though the mechanism by which rosemary inhibits rancidity may have also helped maintain the stability of the red pigment as well.

8.5 TBA Analysis

TBA results (Figure 24) strongly confirm rosemary oleoresin as an effective antioxidant. Values less than 1.0 were maintained throughout the test period for rosemary treated samples. These values are very much lower than values obtained in the untreated samples which had values greater than 2.0 on day 7, reaching values greater than 16.0. These results are consistent with tests conducted on mechanically deboned turkey meat (Barbut et al., 1985;

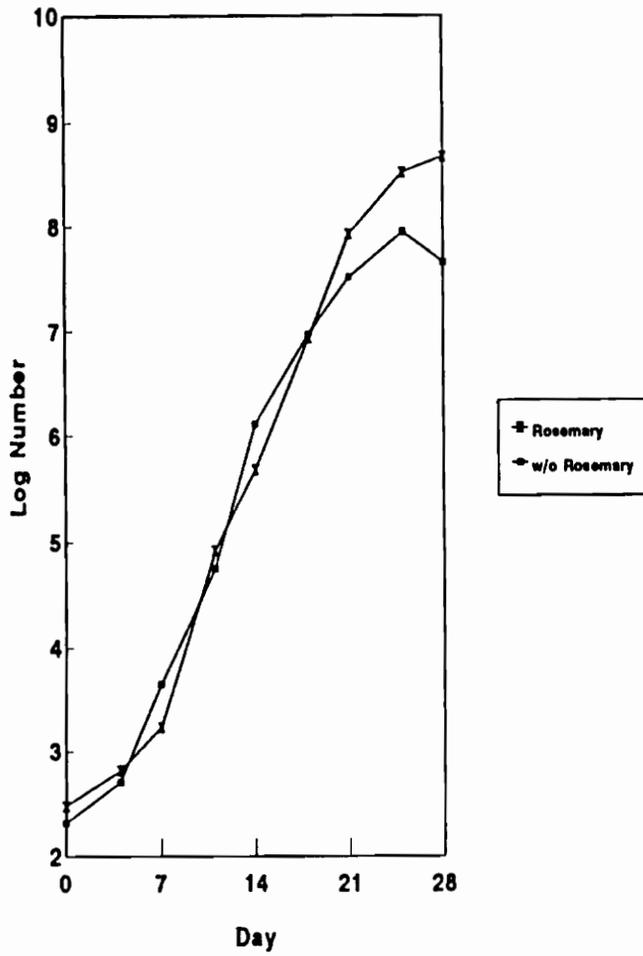


Figure 18: Lactic Acid Bacteria Results of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored At 1°C.

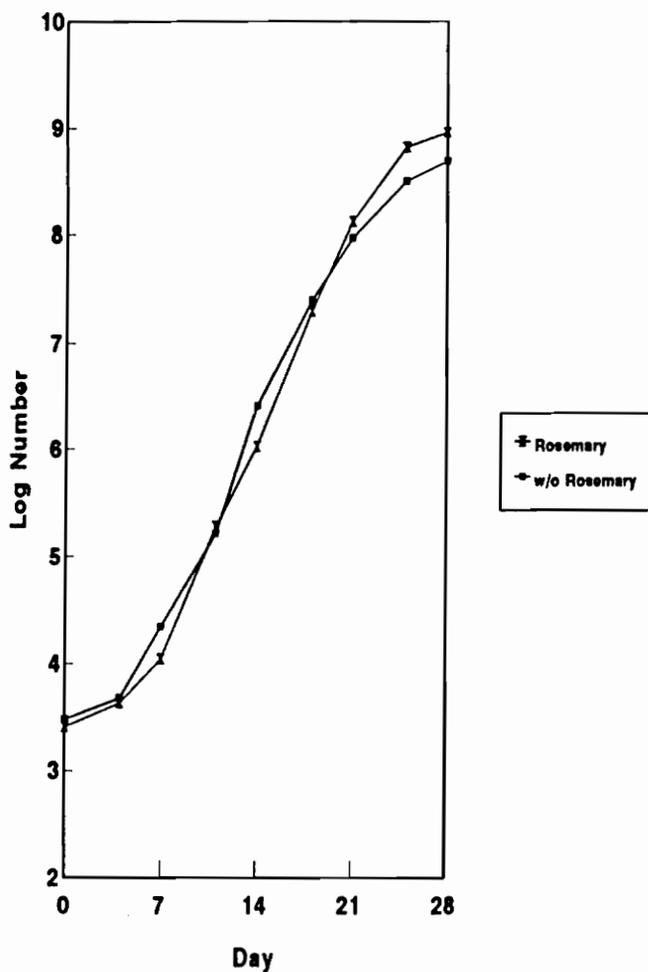


Figure 19: Psychrotrophic Bacteria Results of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored at 1°C.

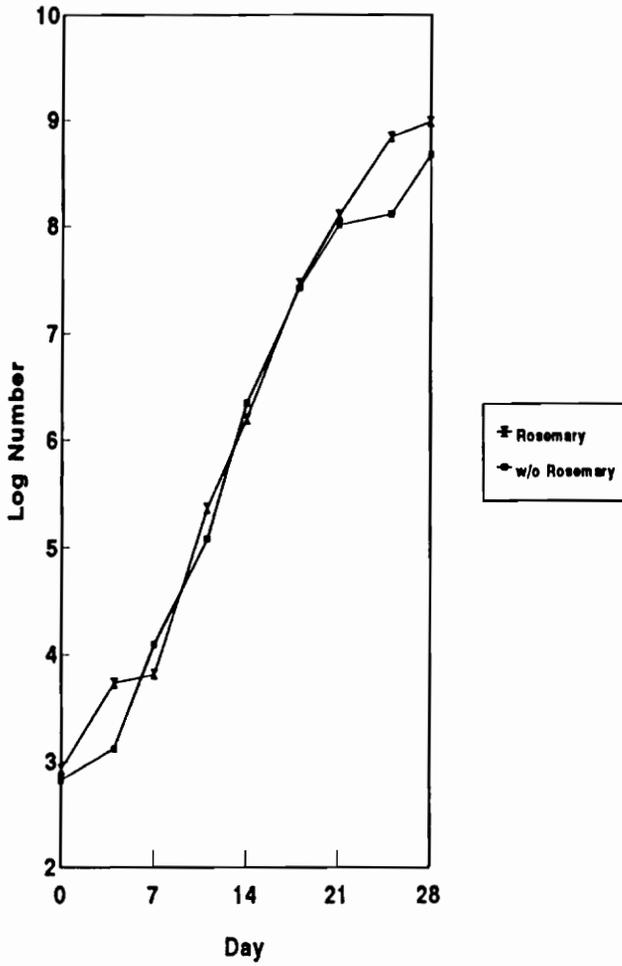


Figure 20: Anaerobic Bacteria Results of MAP Ground Turkey Thigh Meat Treated with 0.1% Rosemary Oleoresin Stored at 1°C.

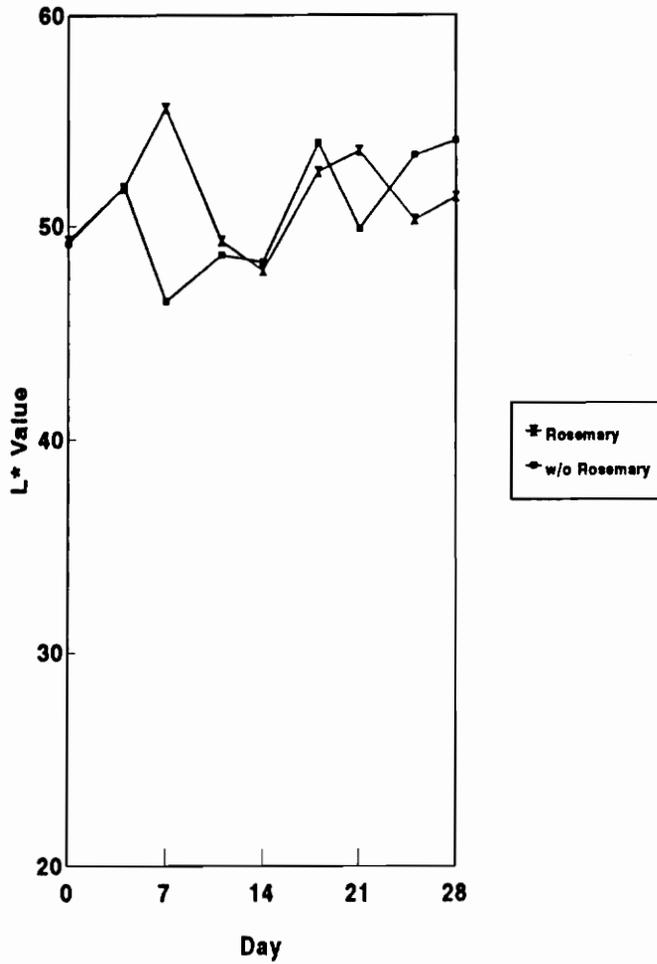


Figure 21: L* Color Values of MAP Ground Turkey Thigh Meat Treated with 0.1% of Rosemary Oleoresin Stored at 1°C.

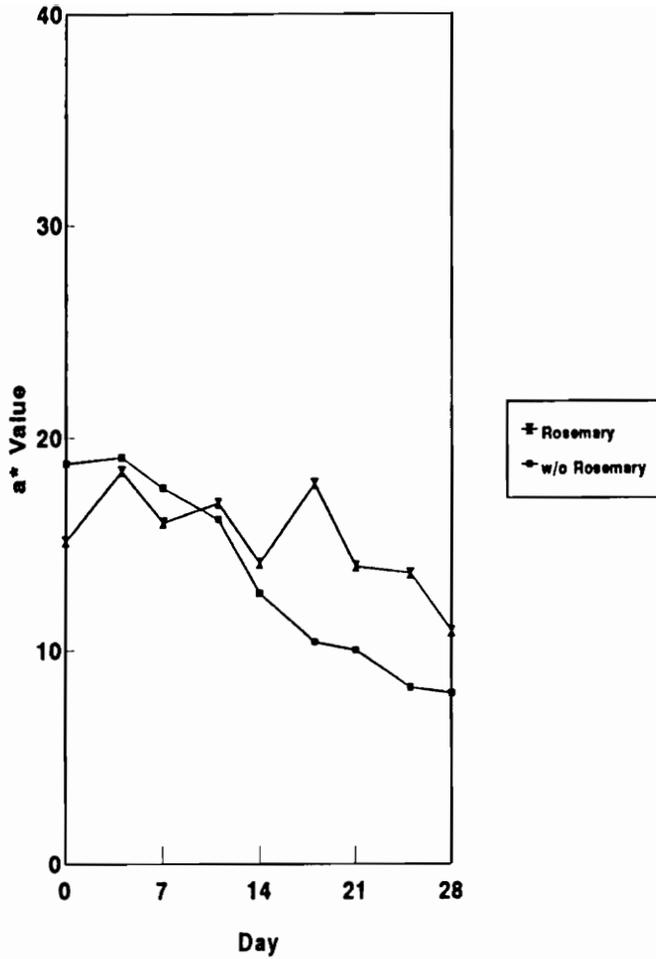


Figure 22: a* Color Values of MAP Ground Turkey Thigh Meat Treated with 0.1% Rosemary Oleoresin Stored at 1°C.

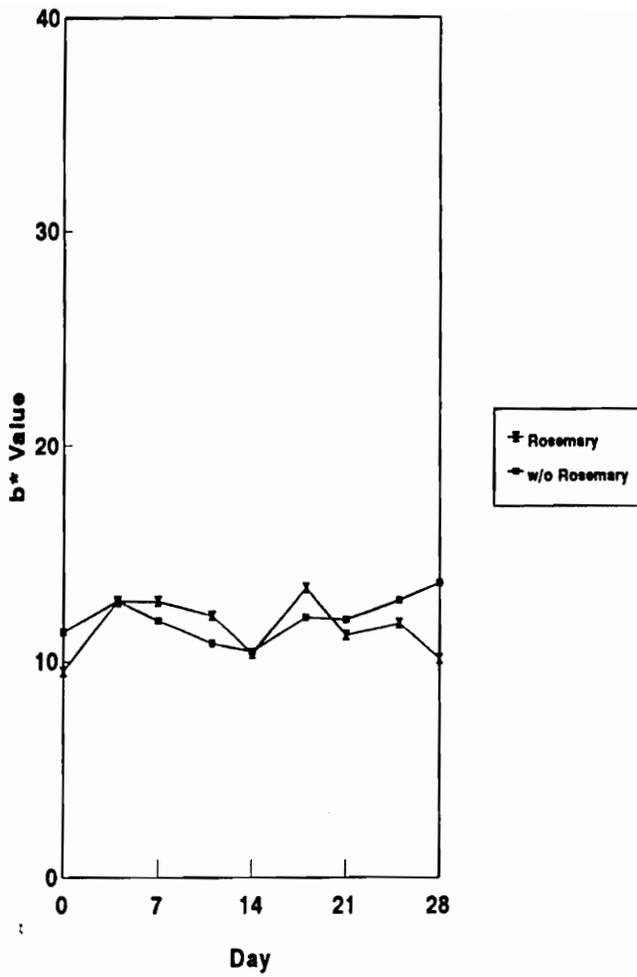


Figure 23: b* Color Values of MAP Ground Turkey Thigh Meat Treated with 0.1% Rosemary Oleoresin Stored at 1°C.

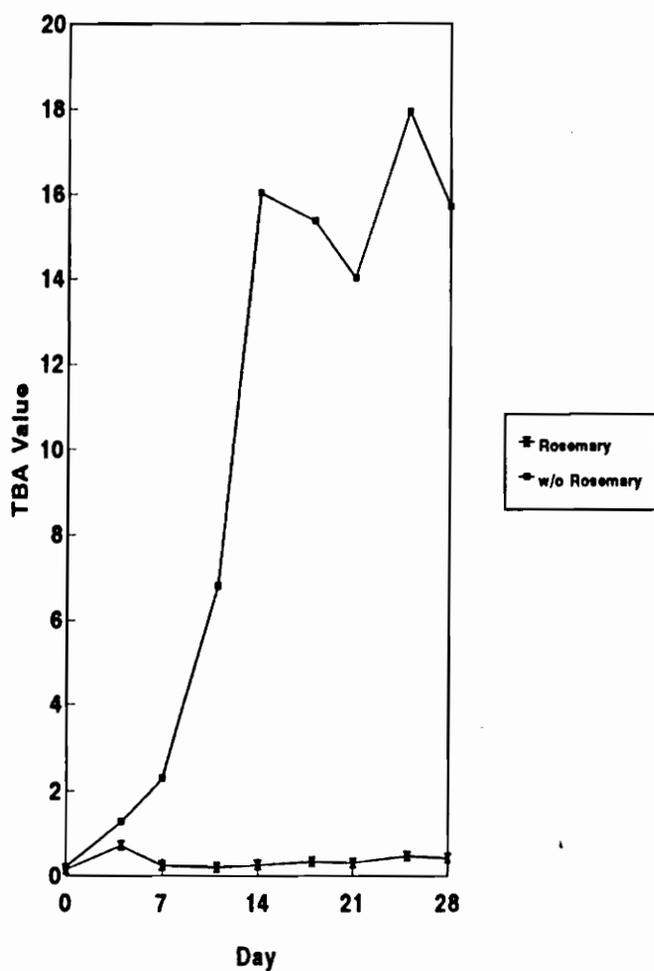


Figure 24: TBA Values of MAP Ground Turkey Thigh Meat Treated with 0.1% Rosemary Oleoresin Stored at 1°C.

McNeill et al., 1988) which is also highly susceptible to oxidative deterioration.

V. SUMMARY AND CONCLUSIONS

In summary, the 100% CO₂ treatment was most effective in maintaining low microbial counts, inhibiting rancidity, and retaining over-all taste. The 80% O₂/20% CO₂ treatment provided the bright red oxymyoglobin color up to day 14. This color changed to a washed out brown after day 14 due to the oxidation of the meat causing a change in the pigment. The 100% CO₂ treated samples exhibited the best red color from day 18 through day 28. TBA values for the 100% CO₂ treatment maintained values below four for the entire test period. The high O₂ treatments had TBA values above five on day 12, reaching values of 18 by the end of the test period. The level of fat was not a significant variable in the study.

Rosemary oleoresin was effective in fat oxidation inhibition. TBA values for rosemary samples were lower than all other treatments in this study. The oleoresin also maintained the red color in the meat for a longer period of time in comparison with the 80% O₂/20% CO₂ treatment without rosemary. However, the 100% CO₂ treatment without rosemary had a higher a* value (redness) after day 21 than did the rosemary treatment.

Future studies with ground turkey thigh meat might include the addition of low levels (5-10%) O₂ in the high CO₂ treatment in an effort to maintain red color during the first 7 days of storage. A microbiological study is needed to determine each treatments effect on selected pathogens, such as Listeria monocytogenes and Clostridium botulinum. A sensory panel to determine visual acceptability of each treatment would be useful.

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VII. APPENDIX

Panelist: _____

EVALUATE ALL THE TEST SAMPLES BY USING THE REFERENCE SAMPLE AS THE STANDARD.

- 1) Taste the reference sample and evaluate.
- 2) Taste each sample and evaluate for rancidity and over-all taste. DO NOT SWALLOW THE SAMPLES.

Reference Sample			
	<u>Odor</u>	<u>Taste</u>	<u>Comments</u>
Excellent	_____	_____	_____
Good	_____	_____	_____
Borderline	_____	_____	_____
Poor	_____	_____	_____
Inedible	_____	_____	_____

Sample Z

Not Rancid	Very Rancid
Good Over-all Taste	Poor Over-all Taste

Sample N

Not Rancid	Very Rancid
Good Over-all Taste	Poor Over-all Taste

Sample E

Not Rancid	Very Rancid
Good Over-all Taste	Poor Over-all Taste

Sample S

Not Rancid	Very Rancid
Good Over-all Taste	Poor Over-all Taste

Sample A

Not Rancid	Very Rancid
Good Over-all Taste	Poor Over-all Taste

VITA

Beth A. Sonneville was born September 1, 1960 in Joliet, IL. She was raised in Moline, IL. for the majority of her first eighteen years, except for three and a half years when she lived in Vicenza, Italy with her family. She enlisted in the U.S. Navy in February 1978 and graduated from Alleman High School, Rock Island, IL. in June 1978. Beth was on active duty in the U.S. Navy from November 1978 until November 1983, the majority of her time was spent in Washington, D.C. She has been affiliated with the U.S. Naval Reserve since November 1983.

Ms. Sonneville returned to school in August of 1984 and was enrolled for two years at George Mason University, Fairfax, VA. She graduated with her B.S. in Food Science and Technology in December 1989 from Virginia Tech. In January 1990 she began working on her M.S. degree in Food Science at Virginia Tech.

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