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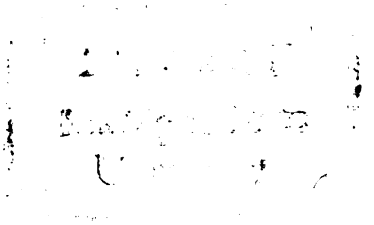

This is to certify that the

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INFLUENCE OF ANTIOXIDANTS AND PACKAGE ENVIRONMENT ON STABILITY OF TURKEY PRODUCTS

presented by

NANCY ANN KING

has been accepted towards fulfillment of the requirements for

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Major professor

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INFLUENCE OF ANTIOXIDANTS AND PACKAGE ENVIRONMENT ON STABILITY OF TURKEY ROASTS

by

Nancy King

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ABSTRACT

INFLUENCE OF ANTIOXIDANTS AND PACKAGE ENVIRONMENT
ON STABILITY OF TURKEY ROASTS

by

Nancy King

Commercially prepared turkey breast meat roasts were packaged using Saranex™, polyethylene (PE) and a butylated hydroxyanisole (BHA) impregnated coextruded polyethylene film (PE + BHA). Package environments included vacuum, nitrogen, and air environments. All products were stored at -18°C for six months. Lipid oxidation (warmed over flavor) was monitored by thiobarbituric acid (TBA) values, and sensory panel scores. TBA values of the turkey roasts were initially high (approximately 3) and there was considerable variation in this initial measurement. At the end of the storage period, mean TBA values of the product were lowest for turkey meat in PE + BHA film, followed by Saranex™ and PE film in that order. Packaging environments made no significant difference in lipid oxidation of turkey roasts as indicated by TBA values. Storage time had a greater influence on deterioration of flavor and color in turkey roasts than did packaging films or environments. BHA from the PE-BHA packaging film migrated into the turkey fat and may have controlled the extent of lipid oxidation.

To my parents with my love, respect and admiration

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INTRODUCTION

Poultry products have received increasing popularity and demand in recent years. Turkey products, in particular, have contributed substantially to improving the market potential of poultry products, as well as to the growth of the industry. Trends for further processed turkey meat show that in 1976, 608 million pounds of turkey meat were further processed and this increased to 909 million pounds in 1980 (Brown, 1981). It has been estimated that 46 to 48% of the turkey crop in 1981 was cut up or further processed (Brown, 1981). Dawson (1975) reported an increase in the use of turkey in forms other than whole birds from 250 million pounds in 1965 to 900 million pounds in 1974. This in an average increase of 70 million pounds yearly.

During product distribution and subsequent entrance into the supermarket and home, meat products have many opportunities to become intentionally or unintentionally frozen. The handling and freezing of the product during this distribution process can be very critical to the lipid stability and overall acceptance of the product. This project was initiated based on a need for commercial processors to know more about stability of precooked turkey products during frozen storage. This study was designed to evaluate several procedures or methods for minimizing oxidation of lipids in a typical precooked turkey product. A commercial turkey breast meat product was selected to eliminate one of the variables--meat source. This product is also one of the turkey products on the market which has caused some problems in marketing due to development of rancidity or off flavors during storage. Therefore, the objectives of this project were (1) to determine the effect of packaging

materials on oxidation in a turkey product during frozen storage; (2) to evaluate the effects of packaging environments on oxidation in a turkey product during frozen storage; and (3) to evaluate migration of butylated hydroxyanisole (BHA) from the packaging material into the turkey products.

REVIEW OF LITERATURE

Poultry Meat

Poultry meat is nutritionally excellent, economically priced and readily available for convenient use by today's consumer. The proteins of the meat are similiar to those of other livestock (Millares and Fellers, 1948; Scott, 1959). Scott (1956, 1958) determined the nutrient composition of the edible proteins of the raw and roasted turkeys of various types and ages and compared them to chicken, duck, beef, lamb, and pork. The protein content is relatively high for both chicken and turkey meat at approximately 20-24% and the fat content ranges from 1-2% in the breast meat to 4-5% in the leg meat (Watt and Merrill, 1963; Palmer and Bowers, 1972). It has been generally accepted that poultry fat contains a high percentage of the unsaturated fatty acids and a low level of cholesterol (Pearson et al. 1977).

Of special concern to food processors is the retention of freshly cooked flavor and prevention of stale and rancid flavor development in precooked frozen turkey products. The stability of flavor in turkey products is related to the inherent composition of meats, to cooking methods, to package atmosphere and to the storage conditions. According to Palmer and Bowers (1972), the qualities desired in cooked poultry meat are tenderness, juiciness, presence of typical poultry flavor, and the absence of off-flavor, microbiological spoilage and other chemical hazards. This rancid or off-flavor problem has been associated with the lipid fraction of the poultry meat and in particular the tissue or intramuscular lipids (Younathan and Watts, 1960; Love and Pearson, 1971).

Development of Warmed Over Flavor

Tims and Watts (1958) first suggested the role of tissue lipids in rancidity after noting a rapid flavor deterioration in cooked meats during refrigerated storage. They proposed that this change in flavor was caused by the oxidation of highly unsaturated protein bound phospholipids. Because of a high content of polyunsaturated fatty acids, the phospholipids are very labile to oxidation (Love and Pearson, 1971; Lea, 1957). This factor gives phospholipids their importance in the determination of meat quality in spite of their relatively small content in meats. El-Gharbawi and Dugan (1965) reported that phospholipids are oxidized first followed by the autoxidation of the neutral lipids. In examining the effects of triglycerides and phospholipids in the development of warmed over flavor (WOF) or off-flavors, Igene and Pearson (1979) found that total phospholipids contributed to the development of warmed over flavors in both beef and poultry.

Poultry meat and fish (Watts, 1954, 1962; Acosta et al. 1966; Younathan and Watts, 1960) are higher is phospholipids than the red meats such as beef (Pearson et al. 1977). Researchers have shown that poultry dark meat contains more phospholipids than white meat (Peng and Dugan,1965; Acosta et al. 1966). Contrasting results were obtained by Katz et al. (1966) indicating that chicken dark meat has only about half as much phospholipid as white meat. Cooked meat has an apparent higher phospholipid content than raw meat whether it is expressed as a percentage of fat or as a percentage of total tissue (Campbell and Turkki, 1967; Fooladi, 1977).

Poultry meat is more unsaturated than beef, lamb or pork (Scott, 1958; Acosta et al. 1966). Pearson et al. (1977) stated that chicken fat is particularly high in oleic and linoleic fatty acids and because of this unsaturated nature, poultry meat is generally thought to be more susceptible to becoming rancid more rapidly than red meats. Turkey meat is most susceptible to the development of rancid flavors or oxidative rancidity closely followed by chicken, pork, beef and mutton (Wilson et al. 1976).

In lipid oxidation, the decomposition of the hydroperoxides influence overall flavor as well as warmed over flavor. One of the principal products associated with lipid oxidation is hexanal, which has been implicated as a component of WOF (Love and Pearson, 1976). Ruenger et al. (1978) in studying WOF in turkey meat found that heptanal and n-nona-3-6-dienal were correlated with WOF. By identifying these products of lipid oxidation, evidence supports that WOF is caused by lipid oxidation (Sato and Herring, 1973).

Lipid Oxidation

Of the chemical constituents of foods, the lipids are the most susceptible to atmospheric oxidation or autoxidation. This oxidative deterioration of food lipids has been shown to be responsible for oxidative rancidity in foods and is characterized by objectionable odors and flavors, deterioration of nutritional value and changing physical properties (Dugan, 1961). Deleterious autoxidative reactions are accompanied by various secondary reactions having oxidative and nonoxidative character (Gray, 1978). The generally accepted mechanism of

lipid oxidation proceeds through a free radical chain reaction mechanism which occurs in three stages: initiation, propagation and termination.

Initation takes place when a labile hydrogen is abstracted from a site on the lipid (RH), with the formation of free radicals ($R^{\bullet}$). Initiators in this reaction include light, heat, heavy metals and oxygen.

$$R_1H \xrightarrow{\text{initiators}} R_1^{\bullet} + H^{\bullet}$$

(free radical)

Propagation involves the combination of fatty free radicals with molecular oxygen to form peroxide free radicals. These compounds are then able to abstract another methylene hydrogen to form further free radicals and hydroperoxides which are capable of perpetuation of the chain reaction.

$$R_1^{\bullet} + O_2 \longrightarrow R_1OO^{\bullet}$$

(free radical) (peroxide free radical)

$$R_1OO^{\bullet} + R_2H \longrightarrow ROOH + R_2^{\bullet}$$

(hydroperoxide)

Termination of the free radical chain mechanism results when free radicals are deactivated and stable with the creation of non-radical end products. Free radical inhibitors (R_I) include antioxidants that may react with the chain continuing free radicals to form inert end products

as a termination step in the chain reaction mechanism.

$$R^{\cdot} + R^{\cdot} \longrightarrow RR$$

$$R^{\cdot} + ROO^{\cdot} \longrightarrow ROOR$$

$$ROO^{\cdot} + ROO^{\cdot} \longrightarrow ROOR + O_2$$

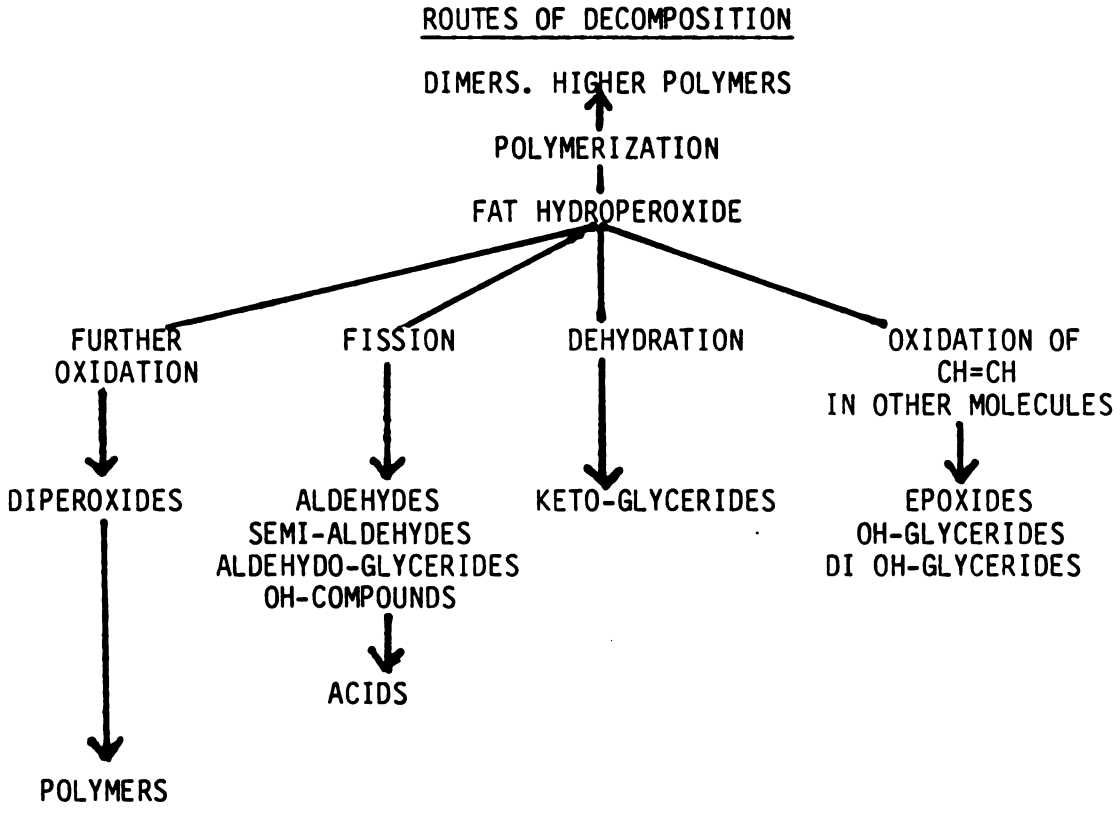
$$R^{\cdot} + R_I \longrightarrow RR_I$$

Additional meat components have been implicated in catalytic roles in lipid oxidation. Some metals occurring in meat in trace quantities, especially ferrous iron, are efficient lipid oxidation catalysts. Research now indicates that ferrous iron is the active catalyst of lipid oxidation in meats (Waters, 1971; Love and Pearson, 1974).
The role of the common meat additive, sodium chloride, in initiating color and flavor changes in cured meat is poorly understood. Some data indicate that trace metal impurities present in salt account for its effects on lipid oxidation (Lea, 1939). However, there is additional evidence for a direct role of sodium chloride in initiation of fat oxidation (Ellis et al. 1968). According to Watts (1962), salt is believed to catalyze the oxidation of stored triglycerides.

Products of Lipid Oxidation

Hydroperoxides are widely considered to be the primary products of the reaction of oxygen with unsaturated lipids. They are colorless and odorless compounds that do not account for the off-flavor associated with lipid autoxidation (Sato and Herring 1973; Watts, 1954). Degradation of hydroperoxides through a series of scission and dismutation reactions

yield the secondary products of lipid oxidation. These secondary degradation products include aldehydes, ketones, acids, lactones, alcohols and unsaturated hydrocarbons and they are thought to be primarily responsible for the off odors and off flavors associated with oxidative rancidity (Lea, 1962; Sato and Herring, 1973). The following scheme as shown by Gray (1978) illustrates some of these routes of decomposition of fat hydroperoxides.



Measurements of Rancidity

Methods of rancidity measurement have been reviewed by Sherwin (1968). Objective methods available for the evaluation of both storage and stability were reviewed by Erickson and Bowers

(1976). According to these researchers, the methods available for determination of lipid stability and oxidation can be classified as methods of oxygen uptake, peroxide formation, and peroxide decomposition.

The TBA test is a measurement of final reaction products and is based on the development and quantitation of a red pigment formed by the condensation of one molecule of malonaldehyde and two molecules of thiobarbituric acid. Malonaldehyde, a three carbon compound resulting from a breakdown of unsaturated fatty acids in food products, reacts with TBA to give a red pigment with a maximum absorption at 530 to 538 nm (Sinnhuber et al. 1958).

Oxidation of muscle lipids has been related to flavor deterioration in cooked meats (Tims and Watts, 1958; Turner et al. 1954) and the thiobarbituric acid test (TBA) has been used extensively to determine the amount of oxidation (Younathan and Watts 1960). The TBA test is useful and convenient because it can be done on the entire food sample and it can be correlated with sensory tests (Younathan and Watts, 1959; Kesinel et al. 1964). For most tissues, off odors and flavors can be detected when the TBA number is 0.5-1.0 (Tarladgis et al. 1960; Watts, 1962). Inconsistant correlations between sensory scores and TBA values doexist. Therefore, this range is not firmly established (Cash and Carlin, 1968).

The consumer of a food product ultimately uses several senses as the primary means of judging the quality of a product. Hence, it is logical that chemical measurement of rancidity in fats and oils should correlate with sensory measurements of rancidity (Sherwin, 1968).

According to Dugan (1976) all objective methods available for determining lipid stability have their own limitations; therefore, sensory methods are necessary for confirmation. Sensory tests can be as simple as having an individual taste or smell a food sample to determine any obvious off-flavors or odors. These tests can be as complex as a multi-membered panel of individuals who have been previously trained for odor and taste evaluations. This is then followed by conduction of a statistically designed sensory evaluation on a series of samples under conditions designed to minimize the bias and human error inherent in such a test.

Effects of Cooking

Both the chemical and physical changes that take place in poultry meat during cooking have been extensively reviewed (Bratzler, 1971; Palmer and Bowers, 1972; Paul, 1972; Meyer, 1975). MacNeil and Dimick (1970) studied the cooking losses of turkey roasts and found that when they were cooked to an internal temperature of 170°F, cooking losses were higher in breast meat than in thigh meat. The effects of endpoint cooking temperature and rate of cooking on sheer values of turkey breast were determined by Goodwin et al. (1962). They stated that breast meat cooked to 88°C and 94°C appeared drier and tended to crumble more than turkey breast cooked to a lower endpoint temperature. Hoke et al. (1967) studied the effect of selected internal and oven temperatures for roasting or braising on the eating quality of the cooked meat. They reported that as internal temperature increased, yields and juiciness of the cooked meat decreased, but the palatability factors increased.

It is generally accepted that development of oxidized flavor or

randicity in meats is accelerated by heating (Younathan and Watts, 1959; Chang et al. 1961; Sato and Herring, 1971; Keller and Kinsella, 1973). Labuza (1971) suggested that the rapid rate of oxidation in cooked meat may be due to the denaturation of the myoglobin during the cooking process. He concluded that the unfolding of the protein allows greater exposure access of the iron to the previously formed peroxide. Younathan and Watts (1959) and Sato and Herring (1971) suggested that the rapid oxidation of lipids in cooked meat is initiated by the conversion of the iron in the porphyrin ring of the myoglobin pigments to the ferric form. Thus, during heating the pigment ferric hemochromogen is an active catalyst for unsaturated fats. The severity of heat treatment seems to be related to the extent of lipid oxidation as reviewed by Yamauchi (1972a). Meat subjected to long periods of heating and/or high temperatures had lower TBA values than did meat cooked at lower temperatures for a shorter period of time (Huang and Green, 1978; Dawson and Schierholz, 1976). Cooked meat has higher TBA values than fresh meat (Keller and Kinsella, 1973). Consumer acceptance of poultry products is strongly influenced by the color of the product (Mugler et al. 1970). Two heme pigments, myoglobin and hemoglobin, make uncooked poultry flesh pink to red. According to Mugler et al. (1970) consumers often object to variation from the normal appearance of uncooked meat or from the normal white to golden brown of cooked turkey. Pool (1956) reported that turkey meat acquired a pink color when oven roasted in an uncovered container.

Effects of Frozen Storage

Frozen poultry meat and the importance of low temperature storage

in retarding rancidity has been the topic of much research (Cook and White, 1939, 1940; Ramsbottom, 1947; Koonz, 1947; Klose et al. 1957). It is generally accepted that lipid oxidation proceeds more rapidly at high temperatures, therefore, the use of low temperature storage is recommended. In frozen meats, the degree of unsaturation as well as the composition of the lipid determines the storage stability of the product (Watts, 1954; Greene, 1969; and Igene, 1976). The lipids in poultry meat, having high relative degree of unsaturation are influenced by storage conditions which makes frozen storage of products of primary importance.

Stadelman (1974) reviewed the storage stability of turkey meat. However, he did not estimate the shelf life of turkey rolls because they are closely linked to product formulation. According to Essary and Rogers (1968), fresh turkey rolls had higher organoleptic values than frozen turkey rolls held at -29^{o}C up to eight months and at fluctuating temperatures. Small flavor losses during low temperature storage of chicken meat have been reported (Jacobson and Koehler, 1970).

Steinberg et al. (1949) indicated that there was a significant decrease in palatability of beef with an increase in the oxygen content of the atmosphere surrounding the meat during frozen storage. According to Hiner et al. (1951), deterioration in the palatability of beef, pork and lamb occurred due to oxidation of fat. They stated that during freezer storage, vacuum packaging produced the most desirable product with the least decline in quality. Hanson et al. (1950) reported that the type of package is of greater importance than freezer storage

temperature for retention of flavor of precooked frozen creamed turkey and chicken. Rancidity in turkey meat, as indicated by the TBA test, was lower in freshly frozen turkey than in precooked frozen turkey roasts before storage at $0^{o}F$ (Cash and Carlin, 1968). Johnson and Bowers (1974b) reported that freshly cooked turkey breast meat had lower TBA scores than precooked and freshly cooked meat stored at $-13^{o}C$ for five weeks. They also reported that phosphate treated precooked and freshly cooked meat had lower TBA values than the control without phosphates.

In precooked frozen turkey roast, Cash and Carlin (1968) found that TBA values varied among duplicate samples from the same slice of meat. They also reported that taste panelists noted that the rancid flavor was present around the edges or perhaps in one specific area of the piece of meat. These results suggest that in initial stages of rancidity, oxidative deterioration may develop unevenly throughout the meat as indicated by off-flavor.

Effects of Packaging

Between the time a food product is processed and packaged and eaten by the consumer, the food travels through a complex distribution and storage system. During this time it is essential that the food remain free from deleterious chemical reactions and physical deteriorations and remains safe and palatable. Food packaging serves four primary functions according to Ball (1967), (1) to protect the food product against contamination by microorganisms and filth; (2) to retard or to prohibit the gain or loss of moisture; (3) to facilitate handling; and (4) to shield the product from light and oxygen. Flexible packaging

is very prevalent among poultry products. There are numerous advantages in the use of flexible packaging material. One important property is the low permeability to moisture, oxygen, nitrogen, carbon dioxide, and desirable or undesirable volatiles (Ball, 1967). Polyethylene is a common packaging material used in the food industry because it is low in cost, strong, tough, pliable, thermoplastic and high in resistance. Disadvantages of polyethylene include its relatively high permeability to gas, low resistance to breakdown by heat and limited transparency.

Gray and Giacin (1980) suggested that the extent to which a package renders protection to a food product is partly determined according to its ability to act as a barrier between the external environment and the internal package environment in which the food is in contact. They further pointed out that by using a high oxygen barrier packaging material, lipid oxidation in a food system can be inhibited or retarded by restricting the diffusion of oxygen into the internal package environment.

Various packaging techniques have been used by the food industry to retard quality deterioration of food products. Packaging materials and methods may be used to reduce the partial pressure of oxygen within the packaged product (Ball, 1967; Labuza, 1971). Vacuum packaging is one such technique in which all available oxygen in removed from the package creating a vacuum around the food product (Ramsbottom, 1971).

Modified gas atmosphere packaging is a procedure that utilizes the gas barrier properties of flexible packaging materials to retard oxidative spoilage in meat and poultry products (Pinto, 1979 and Sander,

1978). In this operation the product is placed in a plastic container with an inert gas such as nitrogen and then the package is sealed.

This inert atmosphere along with a slightly permeable packaging material provides protection of the product by two mechanisms. The inert atmosphere inhibits growth of aerobic bacteria which thrive in direct proportion to the amount of oxygen available. In addition, the permeation of oxygen through the packaging material restricts the growth of anaerobic bacteria (Gray and Giacin, 1980). Rey and Kraft (1971) reported that freezing poultry meat prior to refrigerated storage enhances the occurance of microorganisms if packaging films highly permeable to oxygen are used. They also found that a packaging film impermeable to oxygen reduces the growth and proteolytic and lypolytic activities of psychrophilic bacteria on poultry. This effect is increased by vacuum packaging.

Seideman et al. (1976) found that the higher the degree of vacuum the more effective it was in producing a higher desirability rating in beef cuts. In another study comparing packaging methods for precooked chicken, the meat in polyester/polyethelene laminate pouches packaged under vacuum conditions showed lower TBA values than that packaged without vacuum (Arafa and Chen, 1976). Seideman et al. (1979) in investigating the physical and sensory characteristics of beef packaged in modified atmosphere, suggested that the use of a gas mixture of 20% CO_2/80% N was at least equal to if not superior to vacuum packaging. Mechanically deboned chicken meat and turkey meat had significantly lower TBA numbers when packaged under vacuum or N_2 conditions rather than

O_2 altered and vacuum induced cling packaging techniques. These packaging techniques are far superior to unwrapped samples at 3, 6 and 9 months of storage (Jantawat and Dawson, 1979). Other research indicates that there is no significant difference in flavor scores and rancidity which could be attributed to the effect of packaging materials and conditions during frozen storage (Jeremiah, 1980).

Another technique of packaging involves the treatment of a packaging material with an antioxidant providing protection to a food product from oxidative reactions (Gray and Giacin, 1980). They hypothesized the mechanism of antioxidant activity as being dependant upon the volatility of the antioxidant and the migration or transfer of the BHA from the waxed liner to the cereal product. After incorporation into the product the antioxidant functions in a termination of the free-radical chain oxidation reaction.

Gray and Giacin (1980) concluded that using a packaging material as a antioxidant carrier could result in an overall reduction of costs, even though this packaging material which has been impregnated must be kept tightly wrapped and stored under controlled conditions. Various environmental conditions, including temperature and relative humidity, can result in the oxidation of the antioxidant during storage (Daun et al. 1974), as well as migration of the antioxidant out of the packaging material under time and temperature conditions of storage. Because of these limitations long term storage of these packaging materials may not be desirable.

In researching the migration of plasticizers in polyvinylchloride

films, it was reported that the migration of the plasticizer, di(2-ethylhexyl) adipate increased in the samples of meat with higher fat content. Furthermore, after 48 hours, the migration was almost complete (Daun and Gilbert, 1977).

Antioxidants

Antioxidants are compounds that slow down or prevent the oxidation of autoxidizable materials such as food lipids. The characteristics of the antioxidants, as well as the requirements of the food system, determine the choice of antioxidant (Dugan, 1960). He also indicated that the qualities of an antioxidant are effectiveness at low concentrations, ability to impart desirable characteristics in the food system, low in cost and can be conveniently handled. The generally accepted mechanism of antioxidants and their commercial use have been reviewed by Stukey (1962; 1968) and Uri (1961). Labuza (1971) classified antioxidants into three types which were previously designated by Scott (1965). Type I are the free radical chain stoppers and include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tocopherol. This group consists mainly of phenolic compounds capable of donating a labile hydrogen.

The phenolic antioxidants are widely used in the food industry today. Labuza (1971) reported that phenolic antioxidants offer very good protection in animal fats and most vegetable fats contain high enough amounts of tocopherol to be fairly stable. The use of phenolic antioxidants in stabilizing fats has been reviewed by Pokorny (1971). He indicated that phenolic antioxidants reacted with free radicals and

resulted in a non-propagating end product. Thus, the ratio of hydroperoxide formation and its breakdown products would be reduced. A combination of antioxidants are commonly used in order to obtain effectiveness and the desirable properties of the various individual antioxidants (Dugan, 1960). Many of the phenolic antioxidants are decomposed under processing conditions such as baking or frying; however, BHA and BHT were found to survive and remain effective throughout these treatments (Nickerson, 1967). According to Kraybill et al. (1949), BHA has been reported to be very valuable in the stabilization of food which has been heat processed. Marion and Forsythe (1964) reported a significant delay of autoxidation of turkey lipids with the addition of BHA at .04%. Igene et al. (1976) found evidence that potent natural antioxidants, the tocopherols, are present in meats. Natural tocopherol levels in turkey meat have been shown to be lower than in any other poultry meat. Mecchi et al. (1953) found that the lower tocopherol content of turkey meat compared to chicken meat may be the fat component responsible for superior storage stability of chicken meat.

Applications of antioxidants either alone or in combination can be achieved by numerous methods and have been detailed and summarized by Lindsay et al. (1975). Some of these methods include applying the antioxidant directly to the food, dipping the food into the antioxidant, applying antioxidant as a spray or adding the antioxidant to the packaging material. According to Nickerson (1967) the lowered effectiveness of the antioxidant in flesh type food is caused by the high moisture content of the food in which the antioxidant is not soluble. In

addition, he stated that the fat on the surface of the flesh product will absorb the antioxidant with difficulty. Lund et al. (1976) using various methods of application, concluded that obtaining a uniform distribution of the applied antioxidant was not easily achieved. Stukey (1968) reported some success in achieving product protection by adding a highconcentration of antioxidant to the food packaging material such as the inner waxed liner of a food package. The antioxidant can then migrate to the surface of the packaged product and provide protection to the lipid portion of the food.

MATERIALS AND METHODS

Source of Meat

Turkey meat used in this study was obtained from Bil Mar Foods Inc., Zeeland, MI. Source or sex of the live birds was not identified. Three pound Split Breast turkey roasts were commercially manufactured with 1.5% salt and .5% phosphates at the plant. These roasts were precooked and vacuum packaged in polyethylene bags.

Sample Preparation

Upon receiving the product in the research laboratory, they were cut into one and two pound roasts and then repackaged. One pound roasts were used for chemical analyses and two pound roasts for sensory analyses. Three packaging materials were used in the repackaging: polyethylene (control), polyethylene impregnated with the antioxidant BHA and Saranex™ (Dow Chemical, Midland, MI) package material

The polyethylene used was a 2 mil thick, low density film and served as the control. Saranex™ is a coextruded multilayered thermoplastic film which is basically a layer of Saran resin between outside layers of polyethylene. This film is recommended as being durable for freezer storage. BHA impregnated film (2 mil) is coextruded polyethylene film with the antioxidant BHA impregnated into the film. The inside layer is low density for heat sealing purposes. Pouches were made from these packaging materials by cutting the packaging film to size, folding the sides together and sealing with a temperature pressure controlled heat sealing instrument. When turkey meat was placed in the package the entrance of the pouch was sealed using the Kenfield Vacuum

Sealer (Model C-14 International Kenfield Distributing Co.). Turkey roasts in one third of the pouches were vacuum packaged with the Kenfield vacuum sealer. Another third of the pouches were given a vacuum treatment, followed by backflushing with nitrogen and sealing with the same Kenfield instrument. The remaining third of the samples were sealed in an air environment.

The vacuum operated at 25 in. Hg and the nitrogen was flushed into the pouch at 20 pounds per square inch. After sealing, all of the pouches were stored in a walk in type freezer at -18°C. The design of this experiment is shown in Figure 1. Replicates of each sample were produced in order that each analysis could be performed on 2 individually packaged samples. Samples were taken during frozen storage at 2, 4 and 6 months. All analyses were run in duplicate after samples had been thawed for 24 hours at 4°C.

Proximate Composition

Moisture. The A.O.A.C. (1975, 25.003b) procedure was used to determine the moisture of the initial Turkey product prior to storage. Triplicate 5 g samples were weighed into tared aluminum pans and dried to a constant weight at 100°C (18 hours) in a forced air oven. Moisture was expressed as percent weight lost during drying. The following equation was used:

$$\% \text{ Moisture} = \frac{\text{weight of moisture lost (g)}}{\text{weight of initial sample (g)}} \times 100$$

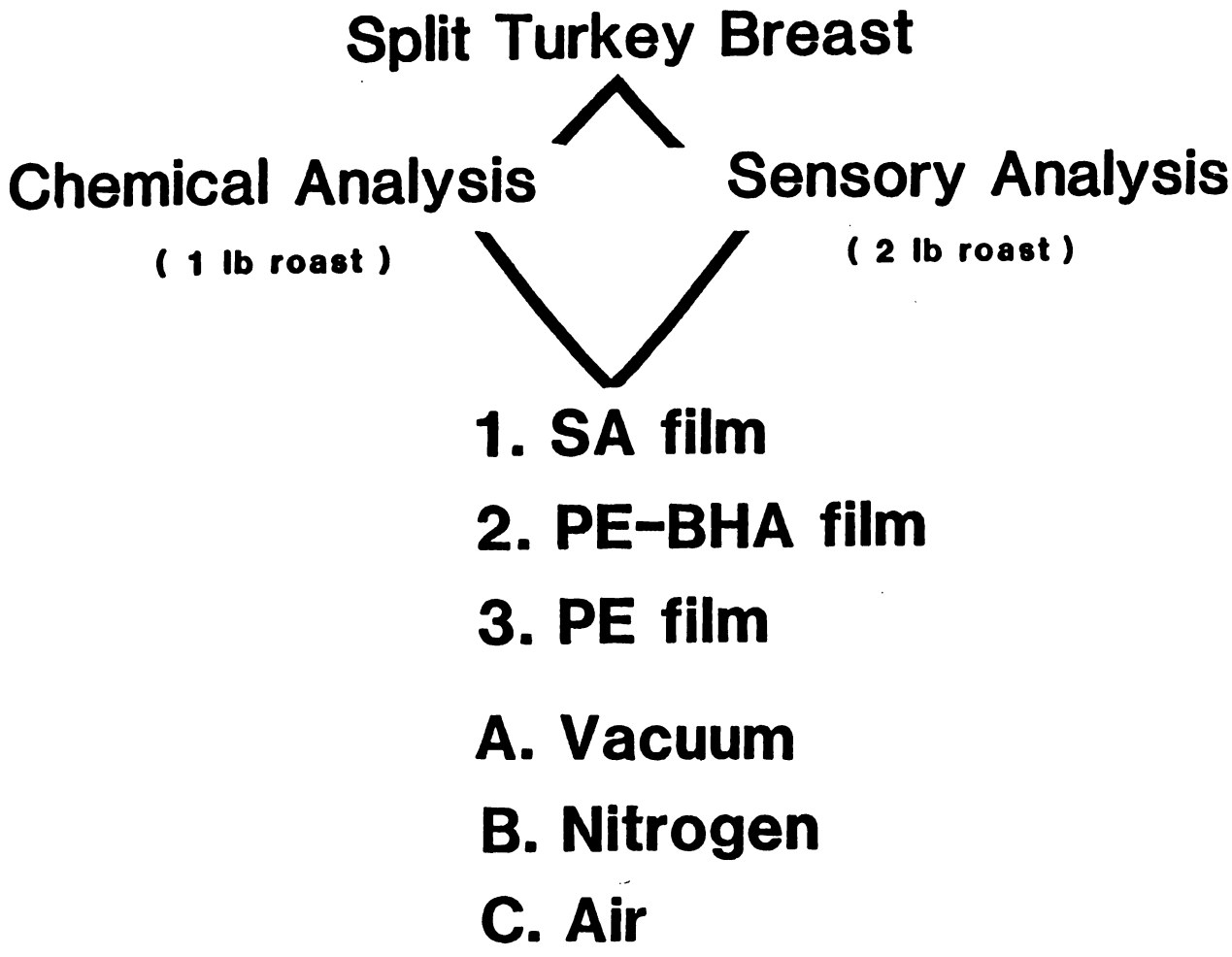


Figure 1. Sample Preparation and Experimental Design for Turkey Roast.

Fat. Solids obtained from moisture determinations were used for Goldfisch extraction (A.O.A.C., 1975, 24.005b). The samples were continuously extracted for three and one-half hours using anhydrous ethyl ether. Ether was evaporated and the lipid extract dried at 100°C for 30 minutes. Total fat was calculated on a fresh weight basis using the weight of the cooled extracted material and the following equation:

$$\% \text{ fat} = \frac{\text{weight of dried extract (g)}}{\text{weight of initial sample (g)}} \times 100$$

Protein. Protein was determined using a modified A.O.A.C. (1975, 23.009) semi-micro Kjeldahl procedure. Triplicate 0.5 g turkey samples were digested by 1 g sodium sulfate, 7 ml concentrated sulfuric acid and 1 ml of 10% (w/v), copper sulfate solution, with heat to a clear pale green endpoint. The digested sample was neutralized with a 35 ml of 50% sodium hydroxide and distilled into 20 ml 2% boric acid. The distillate was back titrated to a colorless endpoint using a standardized 0.1N sulfuric acid with brom cresol green as an indicator. Percent protein was calculated on a fresh weight basis using the following equation:

$$\% \text{ Protein} = \frac{(\text{N of } H_2SO_4)\ (\text{net ml } H_2SO_4)\ (.014)\ (6.25) \times 100}{\text{fresh sample weight in grams}}$$

Ash. Total ash was determined using a variation of the A.O.A.C. (1975, 29.012) method. Triplicate 5 g samples of fresh turkey were weighed into previously ashed and tared Coors 50 ml (size 2) porcelain crucibles and then dried at 100°C for 18 hours. These dried samples were pre-ashed over a Fisher burner. Crucibles were then placed in a muffle furnace and heated at 525°C until a uniform white ash was obtained (approx. 24 hours). Ashed crucibles were held in a desiccator until cool before weighing. Percent ash was calculated as a function of the combustible material on a fresh weight basis using the following equation:

$$\% \text{ Ash} = \frac{\text{weight of ash residue (g)}}{\text{weight of initial sample (g)}} \times 100$$

Chemical Physical Analyses

Lipid Oxidation

2-Thiobarbituric acid (TBA) analyses were done according to the distillation method of Tarladgis et al. (1960) to test for lipid oxidation. A randomly selected 10 g sample of turkey meat was homogenized with 50 ml distilled water in a Vir-Tis macrohomogenizer Model 23 (285 ml flask) for two minutes. Each blended sample was quantitatively transferred by washing with 47.5 ml distilled water to a 500 ml distilling flask with 2.5 ml hydrochloric acid added (4N HCL). Several glass beads were added along with Antifoam A spray (Dow Corning, Midland, MI) to prevent excessive foaming. The distillations were

performed on a unit using a 300 mm Vigreux column attached to a 479 mm Leibig condenser with a 75^{o} elbow. Fifty mililiters of the distillate were collected in a graduated cylinder within 10-15 minutes. Special consideration was given to maintain uniform heating times among distillations. TBA reagent (0.02M 2-thiobarbituric acid in 90% acetic acid) was prepared by dissolving 1.4416 g thiobarbituric acid (Eastman Organic Chemicals, Rochester, New York) with 50 ml distilled water and making a 500 ml volume with glacial acetic acid. To help in dissolving the TBA reagent, an ultrasonic cleaner (Mettler Electronics Corp., Anaheim, California) was used.

The sample distillate was mixed and 5 ml were reacted with 5 ml of the TBA reagent in capped culture tubes (200 mm X 25 mm). The samples were heated for 35 minutes in a boiling water bath and then cooled in a cold water bath for ten minutes. Spectrophotometric quantitation was performed (Beckman DB Spectrophotometer, Beckman Inc., Fullerton, California) using absorbance at 532 nm against a blank consisting of 5 ml of distilled water. Duplicate reactions were run for each distillate. Distilled water was used as the blank (reagent). The TBA number expressed as mg malonaldehyde per 1000 grams of meat was calculated by multiplying the mean absorbance by the constant 7.8.

Extraction of Lipids

Total lipids were extracted from all the turkey samples by a modified procedure of Folch et al. (1957). Approximately 100 grams were homogenized at high speeds in a Vortex homogenizer with a volume of 2:1 cholorform to methanol. The mixture was filtered using a Buchner funnel

fitted with #1 Whatman filter paper and transferred to a separatory funnel to allow the chloroform and the aqueous layer to separate. The solvent layer was evaporated at 20°C by using a rotary vacuum evaporator (Rinco Instrument Co.). Following evaporation traces of chloroform were further evaporated under a N_2 stream. The sample was stored at -18°C when not used immediately.

BHA Analyses

BHA analyses were performed using a Waters Associates ALC 201, 202 High Pressure Liquid Chromatography (HPLC) equipped with a Model 440 absorbance detector at 284 nm with a sensitivity of AUFS=0.02. The column, 30 cm X 3.9 mm was packed with μ-Porasil and the injector system was model U6K. The carrier solvent was chloroform. The flow rate was set at 1.5 ml/min with a retention time of 7.5 minutes. A sample of 50 microliters was injected for each analysis.

The emerging peaks were quantatively identified using retention times of standard mixtures of known concentrations of BHA. Peak areas were calculated quantitatively as the product of peak height and concentration injected. Results were expressed as milligran BHA per gram fat.

Surface Color of Thawed Turkey Roast

After thawing at 4°C for 24 hours, each turkey roast was sliced and the surface color of the slices was evaluated using a Hunter Lab Model D-25 Color and Color Difference meter (Hunter Associates Laboratory, Fairfax, Virginia). Using a white standard, Hunter L,a,b, were obtained for each slice of meat. Two slices from each roast were

evaluated and two readings were made at 90^{o} angles on each slice to average any deviation due to irregular surface refraction.

Sensory Evaluation

Sensory evaluations were obtained by sixteen panelists who were randomly selected from students, faculty, and staff of the Department of Food Science and Human Nutrition. All turkey roasts were thawed for 24 hours at $4^{o}C$ and then each slice was cut into four pieces. Samples were coded with two digit random numbers and evaluated under white light in individual panel booths. Panelists were given four samples at one sitting to evaluate and they returned the following day to evaluate the remaining samples. Panelists were asked to judge only flavor on a scoring system of one to nine, as follows: 9-extremely fresh flavor, 8-very fresh flavor, 7-moderately fresh flavor, 6-slightly fresh flavor, 5-flat (neutral), 4-warmed over flavor (slightly stale), 3-stale, 2-rancid and 1-very rancid. See appendix for score sheet.

Statistical Analyses

The "Statistical Package for the Social Sciences" (Nie et al. 1975) program for the CDC 6500 computer operated by Michigan State University was used to assist statistical analyses. Three-way analyses of variance were determined using "Anova" program. Mean squares were reported after rounding and Tukey mean separations were determined to denote significant differences.

RESULTS AND DISCUSSION

The Initial Product

The proximate composition of the turkey roast is outlined in Table 1. It can be seen that this turkey product has a high protein content, approximately 22%, and a very low lipid content, approximately 2%. The turkey roasts, prior to cooking, had a mean TBA value of 1.4. This value was somewhat higher than anticipated. Possible causes for this high measurement include the method by which the birds were killed and processed, and the holding time of the turkey before use in this product. Following cooking, TBA values of the precooked turkey, prior to storage were evaluated using two individual turkey roasts. TBA values from these roasts are reported in Table 2. These data indicate that TBA values were initially high, with a mean of approximately 3.00. As can be seen from Table 2 there is substantial variance among the samples of the product; varying from a mean of 2.5 to 3.4. This fluctuation and scattering at 0 time among samples could influence the variability in TBA values obtained throughout the study.

Variability in TBA numbers of the meat samples as well as accuracy of the TBA test could have influenced this initial fluctuation. Cash and Carlin (1968) reported similar findings and suggested that early stages of rancidity and oxidative deterioration may occur first in one area, perhaps the outer edge of the meat and is not evenly distributed throughout. The high TBA values of the initial cooked product could be the result of the cooking process or the addition of salt.

Watts (1962) also found that cooked meat had larger TBA values

Table 1. Proximate Composition of Turkey Roast.

COMPOSITION	
Component	Mean %
Protein	22.3
Moisture	72.8
Lipid	2.2
Ash	2.6

n = 3

Table 2. Initial TBA values for two precooked Turkey Roasts.

Roast 1		
Sample	TBA Values	
	1	2
1.	2.25	2.35
2.	2.59	2.59
3.	2.78	2.78
4.	2.35	2.32
Mean	2.49	2.51

Roast 2		
Sample	TBA Values	
1.	3.42	3.37
2.	3.37	3.37
3.	3.46	3.51
4.	3.37	3.35
Mean	3.40	3.40

4 samples per roast, 2 replicates per sample of meat ... n = 8.

than raw meat. In cooked meat phospholipids have been shown to be the lipid component most rapidly oxidized (Younathan and Watts, 1960). According to Lea (1957) the tendency of phospholipids to oxidize rapidly is partially due to their high content of unsaturated fatty acids. An additional possible explanation for the increase in TBA values after cooking is that the raw meat lipid is bound to protein and exists in a

lipoprotein complex. High cooking temperatures could result in the breakdown of this complex. The lipid fraction then could be released and become increasingly susceptible to oxidation attack.

Lipid Oxidation, TBA Test

TBA values of the turkey meat in all of the three package films (not considering environments) over the six months of frozen storage are reported in Table 3. These results are graphically illustrated in Figures 2, 3, 4, and 5. Table 4 reports TBA values for turkey meat in all of the package materials and environments during the six month storage period. Figure 2 shows the mean TBA values of turkey meat packaged in all films (not considering environments) vs. time. Turkey lipids increased in TBA value or rancidity over the six month storage period in meat packaged in all of the films. Turkey packaged in PE + BHA film had the lowest mean TBA value, 3.83, after six months of frozen storage. This is significantly lower than turkey meat in the control (PE) which had a TBA value of 4.69. The largest increase in TBA values in the meat occurred between zero and two months of frozen storage in all of the films.

Table 3. TBA values for Turkey Roasts in Different Package Films During Six Months Frozen Storage.

Package Film	Storage Time (months) 0.0	2	4	6	mean
		TBA Values			
SARANEX™	2.95	3.44a	3.92a	4.19ab	3.73
PE + BHA	2.95	4.15b	4.35a	3.83a	4.00
PE	2.95	4.50b	4.15a	4.69b	4.39
MEAN		3.99	4.13	4.24	

All values within columns that have the same letter are not significantly different as determined by Tukey's test.

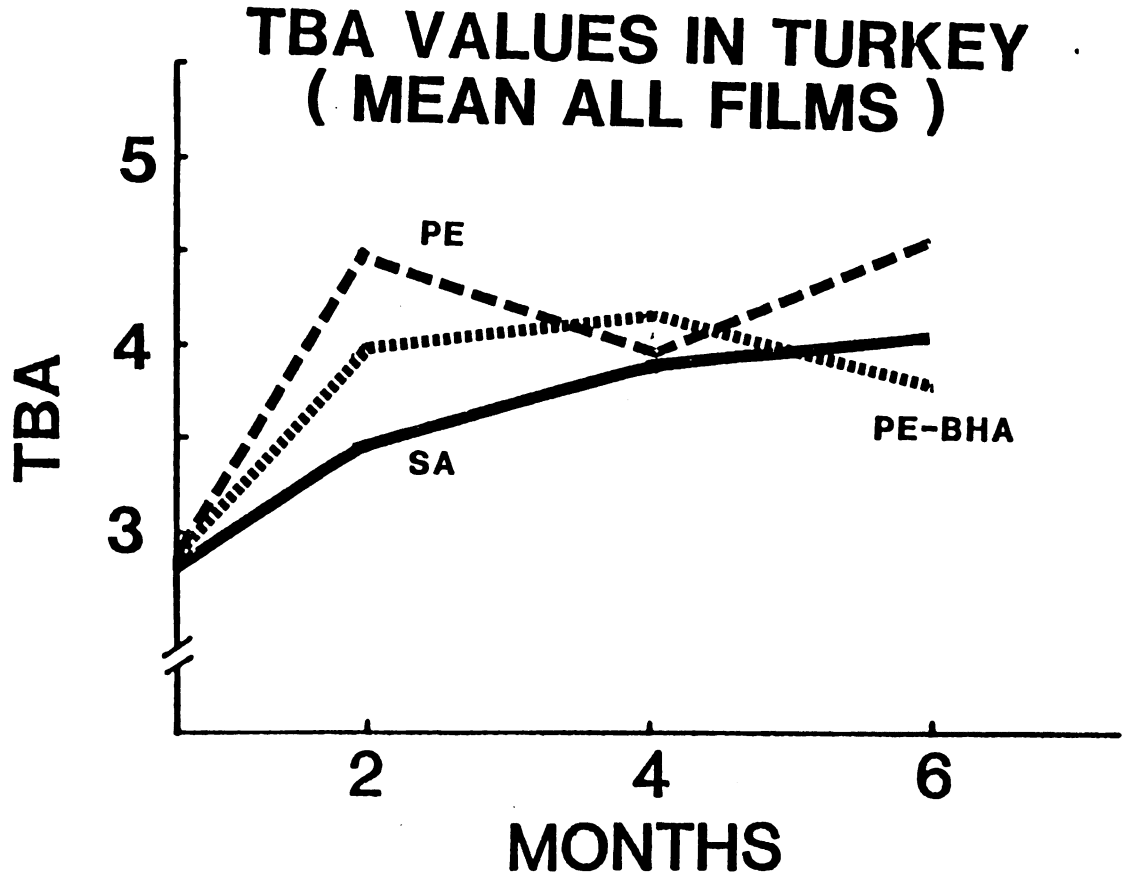


Figure 2. TBA Values in Turkey Roasts (mean of all environments for each film) During Six Months Frozen Storage.

Table 4. TBA Values for Turkey Roasts Different Using Package films and Environments During Six Months of Frozen Storage.

Package Films & Environments	Storage Time (months) 2	4	6
		TBA Values[1]	
Saranex™			
Vac	3.57	4.02	4.18
N	3.60	4.16	4.38
Air	3.14	3.63	3.97
mean	3.44	3.92	4.19
PE + BHA			
Vac	4.06	4.01	3.64
N	4.60	4.51	3.53
Air	3.66	4.80	4.26
mean	4.15	4.35	3.83
PE			
Vac	4.75	4.59	4.77
N	4.19	4.04	4.31
Air	4.47	3.77	5.10
mean	4.50	4.15	4.69

[1] 0 day = 2.95

A three way analysis of variance showed that the main effects of package film and storage time produced significantly different TBA values ($p \leq .001$). TBA values from meats in different package environments, (vacuum, nitrogen and air), were not significantly different. Significant two-way interactions were also found between package film and environment and between package film and time ($p \leq .01$). Statistical analyses of these data are presented in Table 3.

Figure 3 graphically displays the TBA values over the six months of storage for turkey in Saranex™ film. With this film, TBA values of meat packaged in the different environments were not significantly different and samples in Saranex™ showed a very slow increase in TBA values as expected for a low oxygen permeability film. TBA values for meat in PE film during storage are reported in Figure 4. For the turkey product in PE film, there is a much sharper increase in TBA values over the storage period than for turkey packaged in any of the other films. As with Saranex™, TBA values for meat in PE and stored under different environments after six months were not significantly different. The highest TBA values of the experiment were observed in turkey meat in PE film with an air environment, after six months of frozen storage. Because PE films are highly permeable to oxygen, the turkey packaged in PE film was susceptible to oxygen attack or oxidation. Nitrogen flushed packaging gave TBA values in turkey roasts that were slightly lower than those packaged in vacuum or air environments after six months storage. Results for the meats packaged in PE + BHA film after six months indicated an increase in TBA values until month four and then a decrease

Table 5. Analysis of Variance of TBA Values for Turkey Roasts.

Source of Variation	Degrees of Freedom	Mean Square	F Statistic
Main Effects 75.284	7	5.284	10.989*
Package Film	2	6.993	14.543*
Environment	2	.311	.648
Month	2	6.977	14.511*
2-Way Interactions	16	1.376	2.862*
Package x Environment	4	1.649	3.429
Package x Month	6	2.003	4.165*
Environment x Month	6	.563	1.170
3-Way Interactions	12	.408	.848
Package x Environment x Month	12	.408	.848

* Significant = $p \leq .001$

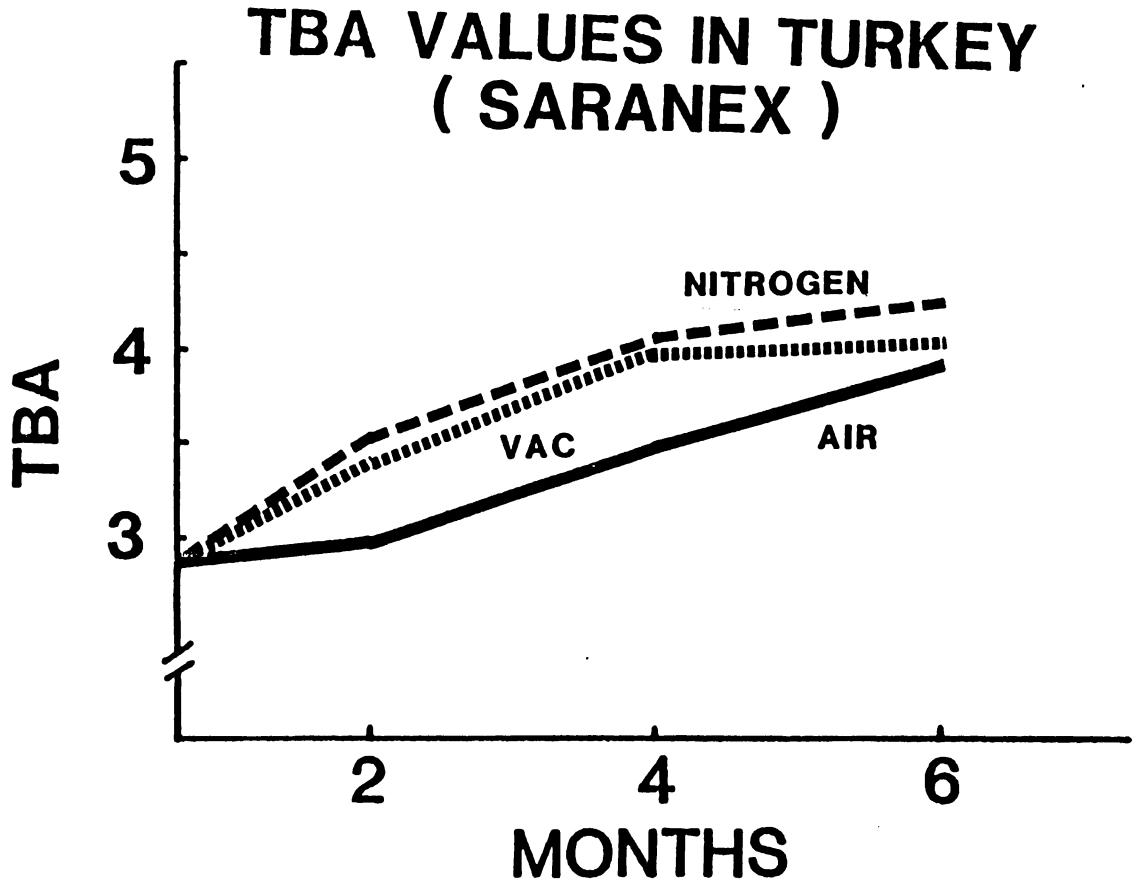


Figure 3. TBA Values in Turkey Roasts in Saranex™ Film During Frozen Storage.

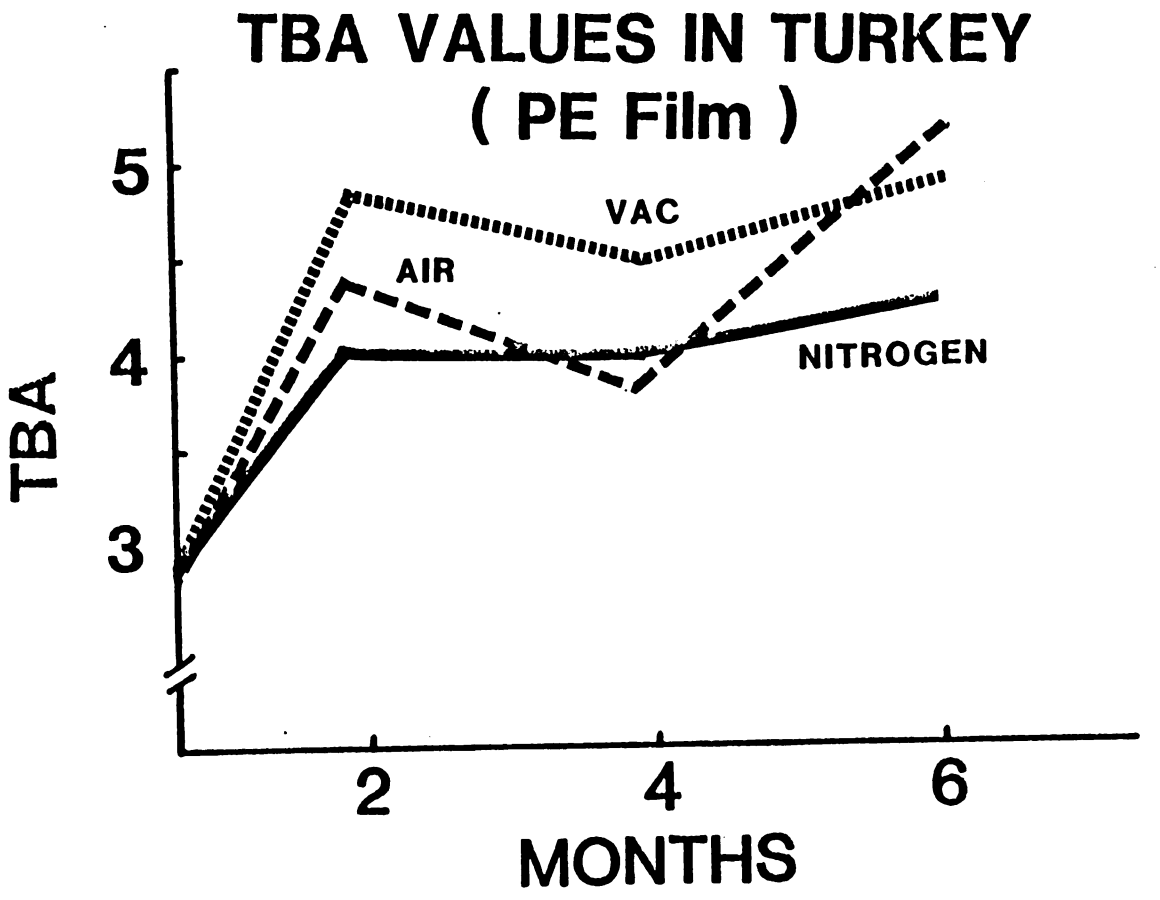


Figure 4. TBA Values in Turkey Roasts in PE Film During Frozen Storage.

(Figure 5). This indicates that the BHA may have had some effect on the TBA values and lipid oxidation in the turkey product. It appears that turkey roasts in vacuum and nitrogen environments in PE + BHA film had slightly lower TBA values than those in air environments after storage. An exact explanation for the decrease in TBA values from month four to six is unknown; however, Jantawat (1976) found that TBA values declined in antioxidant treated samples of poultry during 2 and 4 months of storage. The low fat content (less than two percent) and the resulting difficulty in detecting precise differences in TBA at these low levels of fat could have influenced the TBA data. Igene (1978) using beef fat found much greater differences in oxidation over storage.

BHA Analyses

The migration of BHA from the impregnated PE film into the turkey was determined. Figure 6 graphically shows that BHA did migrate into the turkey product and by the second month of storage was present at a level of 10-20 ug per gram of fat. BHA transfer into the meat in each of the package environments is given in Table 6 and presented graphically in Figure 7. Vacuum packaging appears to promote the migration of BHA most effectively into the turkey product. However, the decrease in BHA values in month 4 may be the result of a faulty vacuum or seal. Vacuum packaging was followed by the nitrogen package environment in the amount of BHA present and air environment had the lowest amount of antioxidant detected in the turkey. As with TBA values, package environment did not make a substantial difference in BHA after six months of storage.

The presence of BHA in the turkey meat can be related to lipid

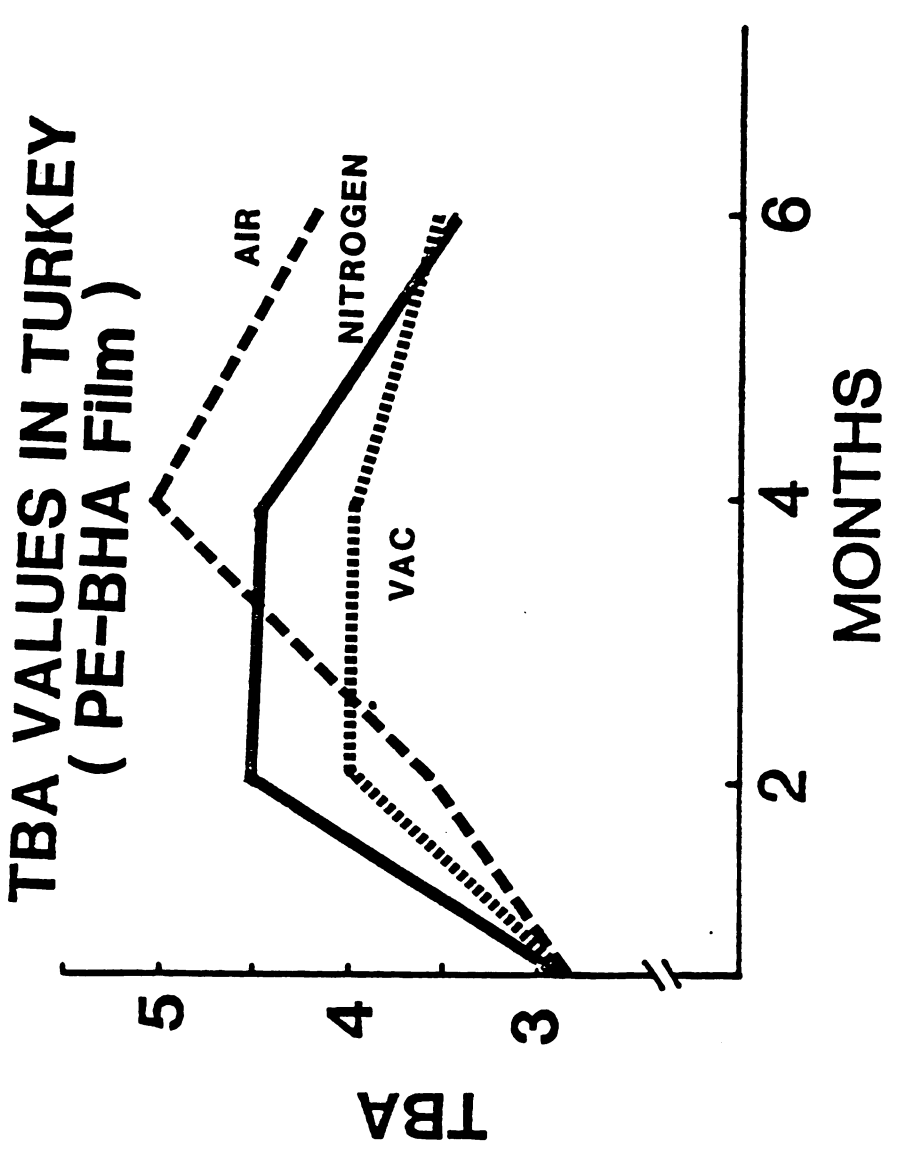


Figure 5. TBA Values in Turkey Roasts in PE + BHA Film During Frozen Storage.

Table 6. BHA Content in Turkey Meat During Frozen Storage

Package Treatments	Storage Time (month) 2 micrograms	4 BHA/g	6 fat
BHA - vacuum	28.31	8.18	20.33
BHA - N_2	15.09	9.82	7.38
BHA - Air	10.94	7.76	5.62

oxidation as indicated by TBA values in this experiment. As stated previously, BHA is present at its highest level after two months of frozen storage. TBA values also show the greatest increase between 0 and 2 months of storage. The possible correlation is that TBA values rose rapidly as the result of a short induction period for oxidation reactions due to the prior cooking; thus, oxidation took place before the BHA was present or available to slow down the oxidative reactions. Very slight changes in TBA values took place between two and six months of storage which could be attributed to the antioxidant present and available to slow down oxidation in the turkey.

In summary BHA does seem to have an effect on TBA values or lipid

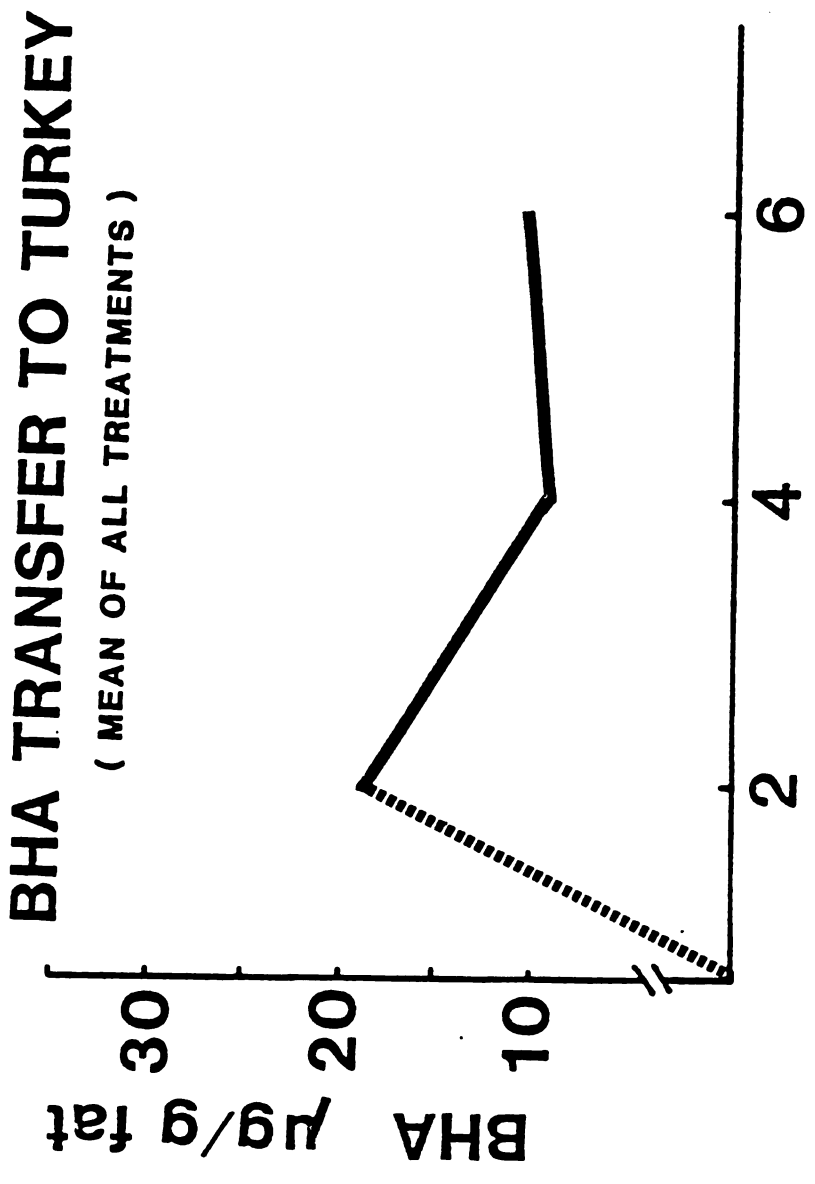


Figure 6. BHA Transfer to Turkey Roasts During Frozen Storage.

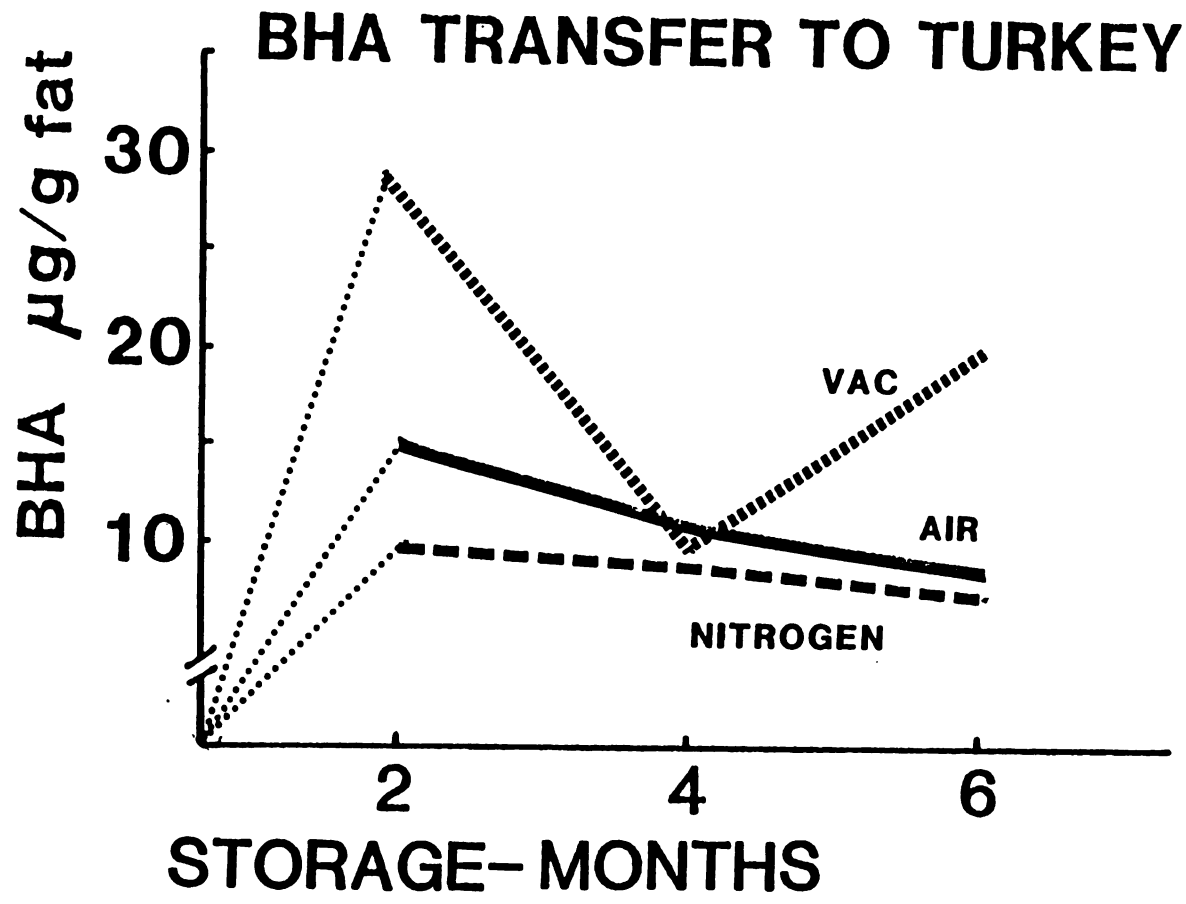


Figure 7. BHA Transfer in Package Environments to Turkey Roasts during Frozen Storage.

oxidation as observed by the small variation in TBA values and the amount of BHA present in the meat packaged in PE + BHA film. From these results once could hypothesize that BHA reacts with free radicals forming products which cannot take part in the autoxidation, however an exact explanation is not known.

Variability in the results of the transfer of BHA from the PE impregnated film into the turkey meat was influenced by the differences in the size and surface area of the turkey roast samples. The variation among TBA values or the extent of autoxidation in the inital product could have affected the variability in TBA values throughout the study. The low fat content could potentially have made it difficult to detect accurate levels and differences of BHA in ug per gram of fat. Detection of the antioxidant in this small amount may be pushing the detection sensitivity to its maximum effective limits; therefore, a range of experimental error may have been present. In addition, light, a catalyst for lipid oxidation was uncontrolled in the experiment which could contribute to some variability in oxidation among the samples exposed to varied light.

Color Evaluation

Color of the turkey product was objectively evaluated using the Hunter Lab Color Difference Meter and L, a, and b parameters were measured. The L-value indicates a parameter ranging from white to black, the a-value defines color from red to green and the b-value gives a parameter ranging from yellow to blue. The initial precooked turkey roast had a pleasing white color with a slight pink cast, characteristic

of turkey breast meat. Prior to storage, this product had an L-value of 73.5, an a-value of 2.4 and a b-value of 11.8. Color measurements were taken at month 2, 4, and 6 of frozen storage and the L-values are reported in Table 7, the a-values in Table 8, and the b-values are shown in Table 9. L-Values are graphically illustrated in Figure 8 and a-values in Figure 9. In general, after six months of frozen storage both the L-value and the a-value declined and the product became darker, more grayish, and lost some of its pink color. Changes in color could be attributed to the oxidation of the pigments associated with turkey meat color.

Examining L-values over the six month storage time, a significant decrease can be found in whiteness, with the initial product having an L-value of 73.5 and the mean L-value after storage being significantly lower. Package films did influence the color of the turkey after six months of frozen storage causing a decline in L-value of the turkey in all three package films. There were no significant differences in L-values of the product after six months among the three package films. The largest decrease in whiteness occurred between 0 and 2 months of storage.

Considering package environments without regard to films, vacuum environment did produce a significantly higher L-value or a more nearly fresh white color than did either nitrogen or air environments. This is as expected because vacuum packaging lessens the availability of oxygen to the turkey, thus creating less opportunity for pigment oxidation and darkening.

Table 7. Color Measurements (L-value) of Turkey Roasts During Frozen Storage.

	Storage Months				Mean of
	0	2	4	6	6 months
Package Film			L-values		
Saranex™	73.5	71.34a	70.27ab	70.01a	70.54
PE + BHA	73.5	72.87b	71.04b	69.63a	71.18
PE	73.5	72.09ab	69.78a	70.22a	70.69
Environment					
Vac	73.5	72.72a	70.42b	71.37b	71.51
N_2	73.5	72.32a	69.40a	69.25a	70.32
Air	73.5	72.26a	71.18b	69.23a	70.89

Values within columns for Package Film or Environment that have the same letters are not significantly different as determined by Tukey's test.

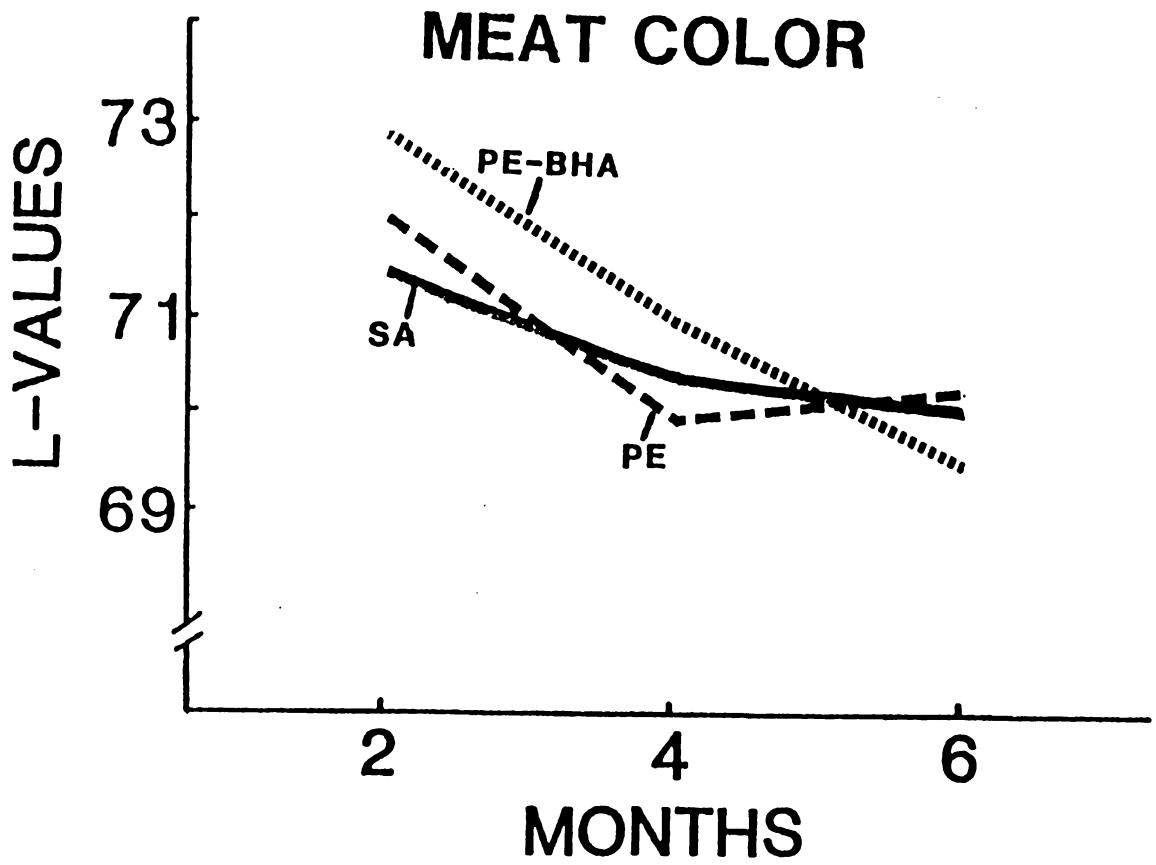


Figure 8. Meat Color (L-Value) Measurements of Turkey Roasts in Package Films During Frozen Storage.

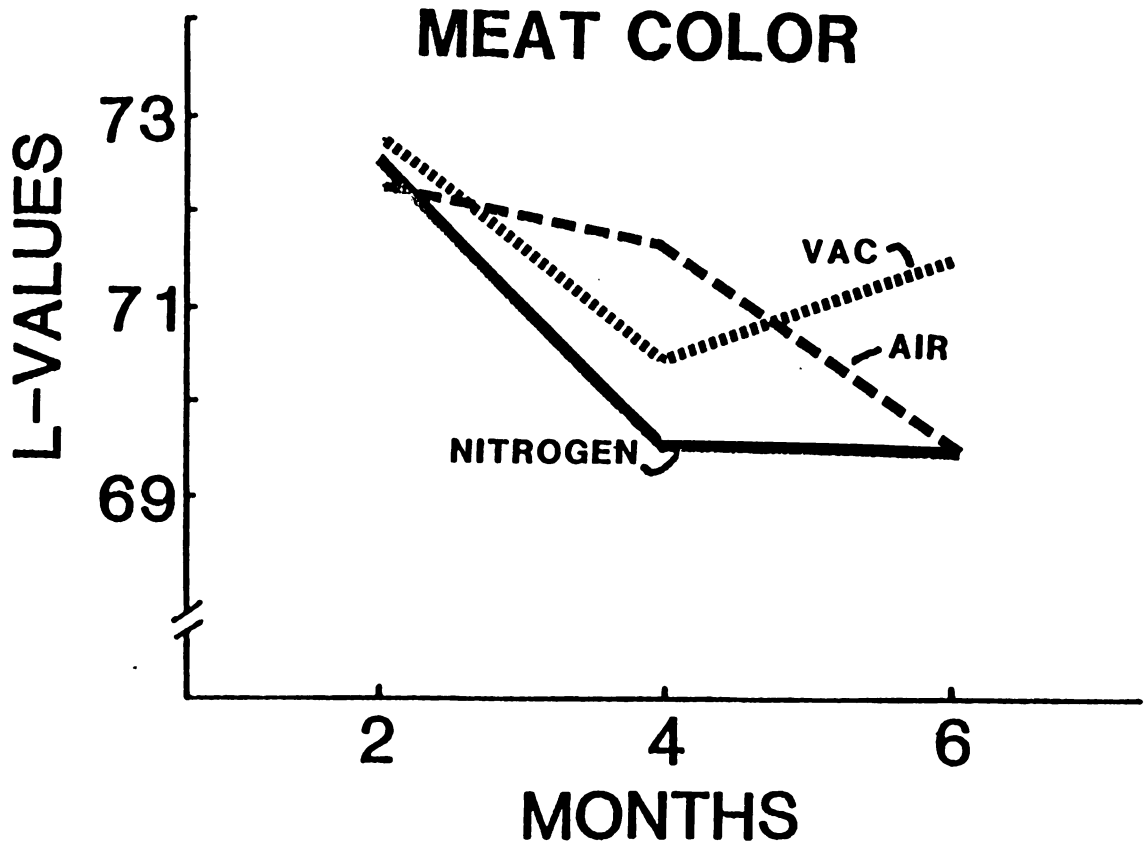


Figure 9. Meat Color (L-Value) Measurements of Turkey Roasts in Package Environments During Frozen Storage.

During the 6 months of storage, a-values decreased indicating a decline in redness or the loss of the pink cast found in the original product. The largest decrease in a-value over storage was reported for turkey in the PE film, which is highly permeable to oxygen. Turkey packaged in Saranex™ retained more of its original pink color than did turkey in PE film and slightly more than turkey in PE + BHA film after the six months storage period.

After six months of storage, vacuum packaging environment did result in a significantly different a-value measurement when compared to the other environments. As with L-value, the greatest decline in a-values occurred between 0 and 2 months. As for b-values, there were slight changes by the end of the storage period.

Table 8. Color Measurements (a-value) of Turkey Roasts During Frozen Storage.

	Storage Months				Mean of 6 months
	0	2	4	6	
Package Film			a-values		
Saranex™	2.4	1.03a	1.09b	1.07b	1.06
PE + BHA	2.4	1.35a	1.49b	.69b	1.18
PE	2.4	1.06a	1.10b	.07a	.74
Environment					
Vac	2.4	1.60b	1.36b	1.83b	1.11
N_2	2.4	1.60b	1.49b	.69a	1.36
Air	2.4	.88a	.83a	.88a	.86

Values within columns for Package Film or Environment that have the same letter are not significantly different as determined by Tukey's test.

Table 9. Color Measurements (b-value) of Turkey Roasts During Frozen Storage.

	Storage Months				Mean of
	0	2	4	6	6 months
Packaging Film			b-values		
Saranex™	11.8	7.70a	7.52b	7.64a	7.62
PE + BHA	11.8	8.24b	7.11a	7.47a	7.61
PE	11.8	7.98ab	7.32ab	7.77a	7.69
Envrionment					
Vac	11.8	7.66a	6.96a	8.02b	7.54
N_2	11.8	8.14b	7.52b	7.28a	7.65
Air	11.8	8.13b	7.48b	7.58a	7.73

Values within columns for Package Film or Environment that have the same letters are not significantly different as determined by Tukey's test.

Sensory Evaluations

Turkey roasts were evaluated by a panel of sixteen members prior to storage and at 2, 4, and 6 months of frozen storage. The same sixteen panelists evaluated samples of the product each month. A sample scorecard is shown in Appendix A-1. Prior to storage, flavor of the turkey was judged to be a score of eight which was described as moderately fresh. Flavor then decreased from a neutral flavor score at 2 months to a slightly stale score at 6 months. Table 10 reports the mean flavor score of turkey meat in all package films at month 2, 4, and 6.

A three way analysis of variance was performed to evaluate the data and no significant two and three way interactions were detected. The results did indicate that the main effect of storage time was significant in producing a decrease in flavor over time. The remaining main effects of package films and package environments made no significant difference in flavor over the six months storage period. Statistical analyses of these data are presented in Table 11. These results appear to agree with Jeremiah (1980) who found that a taste panel failed to observe significant differences among protective wraps in the development of rancid flavors in pork at any storage interval. Hiner et al. (1951) found concurring results and he stated that the palatability of the frozen meat was not affected by the type of protective wrap. Table 12 shows the flavor scores averaged over the six months storage period for turkey meat in each of the package films was approximately 6. This score can be described as neutral, neither fresh nor rancid.

This decrease in flavor as influenced by storage time, was expected

Table 10. Flavor Scores (Mean of All Package Films and Environments) During Frozen Storage.

Storage Time (month)		
2	4	6
mean flavor score		
6.27	6.13	5.57*

* significant = $p \leq .05$

Table 11. Analysis of Variance of Sensory Scores for Turkey Roasts.

Source of Variation	Degree of Freedom	Mean Square	F Statistic
Main Effects	6	7.121	2.754
Package Film	2	1.043	.403
Environment	2	5.133	1.986
Month	2	15.414	14.511*
2-Way Interactions	11	2.584	1.000
Package x Environment	3	2.655	.640
Package x Month	4	.740	.286
Environment x Month	4	5.086	1.967
3-Way Interactions	5	1.177	.455
Package x Environment x Month	5	1.177	.455

* significant = $p \leq .001$

Table 12. Flavor Scores for Turkey Roasts Package Treatments (Mean of Environments for Each Film) During Frozen Storage.

Package Film	Flavor Score
Saranex™	5.98[a]
PE + BHA	6.09[a]
PE	5.94[a]

All values followed by the same letter are not significantly different as determined by Tukey's test.

because it is generally accepted that meat develops off-flavor during storage as it undergoes lipid oxidation. The type of package film or package environment produced little or no detectable differences in off-flavor development during frozen storage. This could be the result of the low level of lipid in the product or insufficient storage time to detect substantial differences in off-flavors. Lipid oxidation may not have advanced to the extent that one could detect differences in flavors.

In addition, it was found that individuals respond to varying degrees of rancid or warmed over flavor, thus when some panelists detected rancid or warmed over flavors, others found it to be an acceptable or fresh flavor. Another difficulty in detecting flavor differences could have resulted from the low (approximately 2%) fat content in the turkey product. At these low levels of lipid it may be difficult to notice differences in lipid oxidation and the subsequent off-flavors.

Panelists indicated that the largest decrease in flavor occurred between the initial product before storage and the product after two months of storage. This correlates with the TBA data which showed the largest increase in TBA values between the initial time and two months storage. Because the product was precooked, it could have had a shortened induction period for lipid oxidation, thus oxidation took place rapidly after storage.

SUMMARY AND CONCLUSION

Commercially prepared turkey breast meat roasts were packaged using Saranex^{TM}, polyethylene (PE) and a butylated hydroxyanisole (BHA) impregnated coextruded polyethylene film (PE + BHA). Package environments include vacuum, nitrogen, and air environments. All products were stored at -18^{o}C for six months.

The proximate composition of turkey roast was evaluated and it was found to be high in protein (22%) and low in lipid content (2%). Before cooking the turkey meat had a TBA value of 1.4 and following the cooking process the TBA values of the turkey roasts had a mean of approximately 3.00. However, there was substantial variance in TBA value after cooking and prior to storage which may have had an influence on the variability in TBA values throughout the study. The increase in TBA values could be attributed to the cooking of the product which could accelerate lipid oxidation.

After packaging the turkey roasts in three films, Saranex^{TM}, PE and PE + BHA, and using three package environments, vacuum, nitrogen and air, the packages were stored for six months at (-18^{o}C). Following six months of frozen storage, the turkey meat in all of the films increased in TBA value or rancidity. Turkey packaged in PE + BHA film had the lowest mean TBA value after the storage period. Between zero and two months of the frozen storage, the largest increase in TBA values occurred in turkey packaged in each of the package materials. The main effects of package films and storage time were significant in influencing TBA values, however, the effects of package environments were not significant.

Turkey roast package in Saranex^{TM} film showed a very slow increase in TBA values as was expected for a low oxygen permeability film. Turkey meat in PE film reflected a sharp increase in TBA value over time as compared to meat in the other two films. The highest TBA values of the experiment were observed in turkey meat in PE (control) film with an air environment after six months of frozen storage. Results for the turkey packaged in PE + BHA film after the storage period indicated an increase in TBA values until month four and then a decrease. An exact explanation for this decline is not known, however, Jantawat (1976) found similar results. Another possible explanation for the decrease in TBA values could be that the antioxidant BHA, did migrate from the packaging material to the meat and did have some effect on lipid oxidation, thus, lowering TBA values.

The migration of BHA from the impregnated film into to turkey meat was determined. Vacuum packaging appears to promote the migration of BHA most effectively into the turkey product. Turkey meat in vacuum package was followed by nitrogen package environments in the amount of BHA present and air environments had the lowest amount of antioxidant detected in the turkey. BHA does seem to exhibit an effect on TBA values or lipid oxidation as observed by the small variation in TBA values and the amount of BHA present in the meat packaged in PE+ BHA film. From these results, one could hypothesize that BHA reacts with free radicals forming products which cannot take part in autoxidation, thus, lowering the amount of malonaldehyde present. However, a precise explanation is not known. Both BHA values and TBA values obtained throughout this study

could be affected by the low lipid content of the product which would make it difficult to detect accurate levels of oxidation or BHA in the low amount of fat present in the turkey roast.

Evaluations of the color of the product were made during the six months of frozen storage using the Hunter Lab Color Difference Meter. In general, after six months of frozen storage both the L-value and the a-value declined and the turkey product become darker, more grayish, losing its characteristic fresh color. Package films did not seem to influence the color of the turkey; however, storage time did cause a decrease in L-value in all three of the package films. Looking at package environments, vacuum environment did produce a slightly higher L-value or a more near to fresh color than did either nitrogen or air environments. During the six months of storage, a-values of turkey roasts showed a decrease in all films indicating a decline in redness or that characteristic pink color found in the orginal product. The greatest decrease in a-value during storage was reported in turkey packaged the PE film which is highly permeable to oxygen. Turkey packaged in Saranex^{TM} retained its original pink color significantly better than did turkey in either of the other films after the six months of storage. Both the L-value and the a-value had the largest change or decrease between zero and two months of frozen storage.

Prior to storage, flavor of the turkey roast was judged to be moderately fresh by a panel of sixteen members. Flavor then decreased from a neutral flavor score at two months to a slightly stale score at six months. Storage time proved to be significant in producing

a decline in flavor scores, but package films and environments made no significant difference in flavor over the six months of frozen storage. Again the greatest amount of flavor change occurred between zero and two months. This decrease in flavor as influenced by storage time was expected because it is generally accepted that meat develops off-flavors during storage as it under goes lipid oxidation. These sensory data agree with Jeremiah (1980) who found that there were no consistent significant differences among the protective wraps evaluated in his study and these data also support the conclusions of Lentz (1971) who stated that the pattern of change in properties such as color and flavor, during frozen storage was not affected by the type of protective wraps utilized.

To briefly summarize, this experiment illustrated that packaging materials, environments and frozen storage time did influence the quality of turkey roasts. Packaging materials impregnated with the BHA did appear to exhibit some migration of the antioxidants. After six months of frozen storage, the turkey packaged in PE + BHA film did produce lower TBA values. This antioxidant impregnated film also exhibited migration of the BHA from the packaging material into the turkey meat. Deterioration of color and flavor of the turkey were influenced more by storage time than by package film or package environment.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Evaluation of BHA migration and its effect on lipid oxidation in a meat product of higher fat content.

2. Quantitive evaluation of migration of BHA both in the packaging material and in the meat product.

3. Evaluation of BHA migration and its effect on lipid oxidation in refrigerated storage and in long term freezer storage of at least one year.

4. Evaluation of migration of synergistic antioxidants impregnated into packaging films, comparing rate of migration and effectiveness against lipid oxidation.

5. Compare this study with a similar study impregnating a less oxygen permeable packaging films with BHA.

APPENDIX

TURKEY ROAST RATING SCORE SHEET

JUDGE'S NAME _____ DATE _____

INSTRUCTIONS: Please evaluate each sample for FLAVOR, using the appropriate scale. Disregard differences in texture, juiciness, and color when evaluating flavor.

FLAVOR EVALUATION	SAMPLE CODE		
Extremely fresh flavor			
Very fresh flavor			
Moderately fresh flavor			
Slightly fresh flavor			
Flat (neutral)			
Warmed over flavor (slightly stale)			
Stale			
Rancid			
Very rancid			

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