QUALITY CHARACTERISTICS OF SOY SUBSTITUTED GROUND BEEF, PORK AND TURKEY SYSTEMS

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ABSTRACT

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By

Claudia Whipple

The use of soy products in school lunch programs and other institutional feeding services have rapidly increased their use of soy products in ground meat systems. More recently, ground beef-soy mixtures have appeared in the retail market. Further research is needed to determine the effects of 30% soy substitutions on various quality characteristics such as, sensory evaluations, lipid and moisture retention, and its effect on the storage quality of cooked meat systems.

An 11-member taste panel evaluated the 0% and 30% soy substituted meat systems for flavor, juiciness, mouthfeel and overall acceptability. Cooking losses were determined for both the 0% and 30% soy substituted systems. Both raw and cooked loaves were analyzed for moisture and total lipid, which was extracted using chloroform-methanol and separated into neutral and phospholipid fractions using an activated silicic acid. The 2-thiobarbituric acid test measured the rate of oxidative rancidity in these systems when products were stored under refrigerated (5^{o}C) and frozen (-11^{o}C) conditions for short periods of time.

The 30% soy substitution did not adversely affect the quality characteristics of the ground beef and turkey systems. But the

soy substitution did lower the flavor, juiciness and overall acceptability scores of the pork system. The use of 30% soy substitution decreased the total and drip loss, whereas it did not affect the volatile losses.

Thirty percent soy in these ground meat systems did not increase moisture retention. While 30% soy did significantly decrease the fat content of the raw beef, pork and turkey meat systems there was no difference between the fat content of the cooked 0% and 30% soy substituted meat systems. The lipids retained in both the 0% and 30% soy substituted beef and pork systems apparently were the same.

Although 30% soy substituted meat systems appeared to have a slightly lower TBA values during refrigerated and frozen storage, soy does not appear to prevent development of warmed-over flavor.

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INTRODUCTION

The utilization of soy products has increased significantly in recent years. On February 22, 1971, the United States Department of Agriculture's Food and Nutrition Service issued Notice 219, which permitted the use of up to 30% rehydrated textured vegetable products to replace up to 30% of the meat or meat alternate portion in the Class A school lunch menu. Approximately 23 million pounds of textured vegetable protein (hydrated weight) were used in the school lunch program during the 1971 - 1972 school year; this figure doubled the following year (Butz, 1974). Since this approval of the use of textured vegetable products, there has also been a tremendous increase in use in hospitals and other institutional food services and more recently hamburger-soy mixtures have become available in the retail market.

A major drawback to the use of soy in meat systems is the consumer acceptance of the finished product. Soy companies advertise that the use of soy in a meat system increases juiciness, flavor and better shape retention (Rakosky, 1974). Soy products often have a characteristic off-flavor described as "beany" or "cereal-like". If the meat formulation is not prepared with enough seasonings to mask the off-flavors, then consumers often find these foods objectionable.

Textured soy products are engineered to look, feel and taste like ground meat; useage in beef systems is widely accepted, however, their use in other systems such as with ground pork or ground turkey, should be investigated more thoroughly.

Many hospitals use textured soy in their ground meat systems. The use of 30% rehydrated soy in a ground beef product reduces by almost 30% the amount of fat present in the raw product. Therefore, one might expect a similar decrease in the amount of fat in the cooked product, thus reducing both the amount of fat and the number of calories. Since two major functional properties of soy proteins are their ability to retain fat and moisture, it would be beneficial to investigate the effects the incorporation of textured soy protein in ground meat systems would have on the retention of lipids and moisture after cooking.

School lunch programs and hospitals often use rotating menus, with the majority of schools being on a three week menu cycle. A common practice in these institutional feeding programs is to store, either by refrigeration or freezing, the cooked left-over meat until it can be used again in the cycle. For example, left-over cooked meatloaf might be frozen for two weeks, thawed, reground and added to another product, such as spaghetti.

A major problem with cooked meat which has been stored at either refrigeration or freezing temperatures is the development of off-flavors and off-odors attributed to the autoxidation of the unsaturated fatty acids present in the meats. Numerous studies have shown that various meat systems, such as beef, pork and turkey, undergo lipid oxidation at different rates when stored under the same conditions. In a few studies the addition of soy to meat systems exhibits various degrees of antioxidant ability. Further studies on the inhibition of the development of a warmed-over flavor (WOF) in ground meat systems are needed.

The objectives of this study are to investigate the use of a textured soy product on the quality characteristics of ground beef, pork and turkey. These characteristics include: sensory evaluations; the effect of soy on cooking losses; the percentages of lipid and moisture; a comparison of the neutral lipids and phospholipids; and the rate of autoxidation which occurs in these soy substituted meat systems when stored under refrigeration and freezing temperatures for short periods of time.

REVIEW OF LITERATURE

Soy Protein Products

Soybean protein products are available in a wide variety of forms for incorporation into numerous food products. Soy proteins exhibit a number of important functional properties, and increase the nutritional quality of the foods to which soy products have been added. Their functional properties, however are the significant factors in determining whether or not the product will be marketable.

Soy Protein Forms

Soy protein products are processed into several forms: flours, grits, concentrates, isolates and textured soy proteins. Processing methods have been reported extensively in the literature (Wolf, 1972; Smith and Circle, 1972; Horan, 1974; Lockmiller, 1973).

Soy flours and grits contain approximately 50-55% protein. They are prepared from flakes following hexane extraction to remove the oil. These flours and grits can contain various levels of fat to yield the following classifications: full fat, high fat, low fat and defatted, the latter of which contains less than 1.0% fat. The amount of carbohydrate present varies with the type of soybean and the method of processing. An average soy flour contains approximately 33.5% carbohydrate, of which 14.0% is soluble and 19.5% is insoluble (Horan, 1974).

Soy protein concentrates contain approximately 70% protein and can be obtained by using an aqueous alcohol or dilute acid leach to remove the soluble carbohydrate from the defatted flakes and flours. Soy isolates are obtained by further processing soy flour to remove the remaining water insoluble carbohydrate. This product contains up to 90% protein.

Textured soy proteins are classified as being either extruded or spun. A thermoplastic extrusion process, using heat and pressure, is used to obtain an extruded product. The spun soy protein product is obtained by preparing an alkalized spinning dope that is forced through a spinneret and the fibers are then coagulated. The size, shape, color, flavor and added nutrients can be altered to yield a wide variety of products.

Functional Properties

Important functional properties, which vary with the type of soy protein product, include: dispersibility, gelation, foaming, emulsion stability, moisture and fat absorption (Smith and Circle, 1972; Rakosky, 1974; Lockmiller, 1973; Wilding, 1974). Retention of functional properties of soy protein products depends on the damage or denaturation of protein during processing, the most critical step being removal of the solvent during preparation of a defatted flake or flour (Horan, 1974). All of these functional properties must be considered before a particular soy product is incorporated into a food product, because of their overall affect on the textural properties of the end product.

Uses of Soy Proteins

Depending on the functional property desired, soy protein products can be utilized in a number of products. Flours and grits are often used in baked products. Since soy proteins cannot form a dough structure, as can the gluten proteins of wheat, soy flour can be used only up to a certain percentage before quality is decreased. Concentrates and isolates are often used in processed meat products, baked goods, dairy type products, frozen desserts and beverages. Legal limits have been established to limit the amount of soy concentrate and isolate in meat products.

Textured soy protein products are used to extend and supplement ground meat systems. With the establishment of the FNS Notice 219 (USDA, 1971) allowing up to 30% rehydrated vegetable protein in a meat product for Class A school lunch menus, there has been an increase in the use of soy as ground meat extenders.

Soy Protein in Meat Systems

Nollman and Pratt (1972) substituted 2.2% textured vegetable protein in meatloaves and evaluated them for cooking losses, texture, juiciness and flavor and the cooked loaves were analyzed for moisture, protein, ash and fat. They noted no differences in cooking losses, protein or the amount of fat content when the soy-loaf was compared to the control meatloaf. Judge _et al._, (1974) used 16% and 24% substitution with rehydrated soy protein concentrate in beef patties and compared bacterial counts, light reflectance, cooking shrinkage and paper release.

Carlin and Nielson (1974) used 30% soy substitution in beef loaves. They investigated the retention of fat and moisture following reheating after loaf frozen storage; differences in flavor; comparison of cooking losses, and the quality of precooked loaves stored at $-4^{o}F$ for 0, 2, 4 and 6 months. Brant (1974) reported the use of textured soy products at levels of 9%, 18% and 27% in beef patties and their affects on the protein, fat, moisture and ash content of the raw versus the cooked state. However, due to "insufficient sample" the proximate analyses of the 0% soy substituted cooked beef patties was not done, so an accurate comparison could not be made.

Quality Deterioration in Stored Meats

When cooked meat is stored, even for relatively short periods of time, the quality of reheated meat is usually less desirable than was the freshly cooked meat. Various terms, such as "stale", "rancid" and warmed-over" have been used to describe these undesirable flavor and odor changes that develop in reheated cooked meat. Tims and Watts (1858) reported that a rapid deterioration in flavor of cooked meat occured after a few hours of storage at refrigeration temperatures. When frozen pork sausage was stored for a relatively short period of time, off-flavor developed which has been recognized in the meat industry as "freezer-taste" (Turner et al., 1954). Pre-cooked beef developed off-odors and flavors more quickly after storage at refrigeration than freezer temperatures (Chang et al., 1961). Cash and Carlin (1968) reported that the development of off-flavor was lower in the cooked meat from raw frozen turkey roasts than from roasts pre-cooked before storage at 0^{o}F.

Lipid autoxidation is responsible for undesirable changes in odor, flavor and color (Tims and Watts, 1958; Greene, 1969). Raw and frozen meat gradually deteriorate in quality due to lipid oxidation, while lipids of cooked meat oxidize much more rapidly.

Mechanism of Lipid Autoxidation

The mechanism for lipid autoxidation has been reported extensively in the literature (Dugan, 1961; Sherwin, 1972; Sato and Herring, 1973; Schultz et al., 1962). The free radical mechanism involved in oxidation of lipids is believed to take place in three stages: initiation, propagation and termination.

Initiation involves the formation of a free radical (R·) from an unsaturated fatty acid (RH) as follows:

$$RH + O_2 \text{ —— } R\cdot + OH$$

Initiators of autoxidation can be light, perticularly ultra-violet, heat and heavy metals, such as copper and iron.

Propagation involves the formation of peroxide free radicals (ROO·) from the fatty acid free radicals (R·). These compounds are then capable of abstracting another methylene hydrogen from another fatty acid to form further free radicals (R′·) and hydroperoxides (ROOH). This reaction can be summarized as follows:

$$R\cdot + O_2 \text{ —— } ROO\cdot$$

$$ROO\cdot + R'H \text{ —— } ROOH + R'\cdot$$

This free radical chain mechanism will continue until termination occurs when non-radical species are formed. A few of these species are shown in the following reactions:

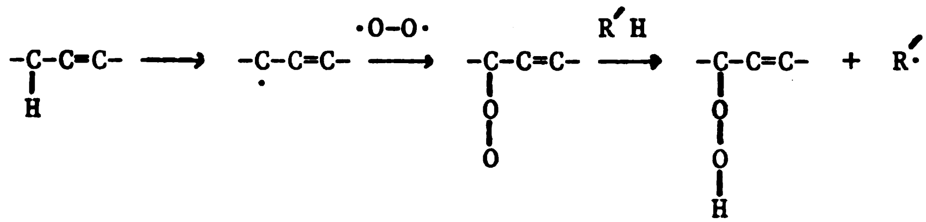
$$R\cdot + R'\cdot \text{ —— } RR'$$

$$R\cdot + R'OO\cdot \text{ —— } ROOR'$$

$$ROO\cdot + R'OO\cdot \text{ —— } ROOR' + O_2$$

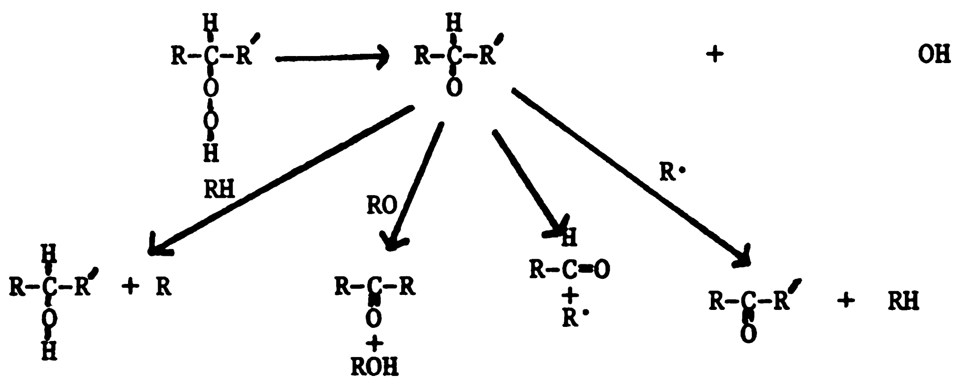
The R· may be a free radical inhibitor, such as an antioxidant, which may react with the chain-continuing free radicals to form inert end products (Dugan, 1961).

Unsaturated fatty acids are much more susceptible to autoxidation due to the ease of removal of the αhydrogen to the double bond. Methylenic hydrogens situated between two double bonds are much more susceptible to free radical attack than those adjacent to one double bond (Gunstone and Hilditch, 1945). The free radical formation, addition of oxygen and eventual addition of another hydrogen, to form hydroperoxides, can be depicted as follows:



Oxidation of various monenoic (such as oleic acid) and dienoic (such as linoleic acid) fatty acids involves abstraction of the α hydrogen and formation of various radical isomers, which, due to shifts in the double bonds, yield numerous isomeric hydroperoxides. For example from oleic acid (C 18:1) there is a possibility of four isomeric hydroperoxides. From linoleic acid (C 18:2) there is a theoretical possibility of three isomeric hydroperoxides: 11-hydroperoxido -9,12-octadienoic acid, 13-hydroperoxido-9,11-octadienoic acid or 9-hydroperoxido-10,12-octadienoic acid. However, the latter two occur more frequently.

The oxidation process becomes more complicated when the primary products of autoxidation, the hydroperoxides, decompose, either by thermal instability or by reacting with other compounds to produce more free radicals, which then contribute to the chain reaction (Dugan, 1961). Hydroperoxides are colorless and odorless compounds and do not account for the off-flavors and odors associated with lipid autoxidation (Watts, 1954). Hydroperoxide degradation products are believed to be responsible for off-odors and flavors characteristic of rancid fats and oils (Kaunitz, 1962; Sherwin, 1972). Hydroperoxides undergo scission to produce free radicals, which in turn react with more compounds to form other compounds, such as aldehydes, ketones, alcohols, acids, lactones and other unsaturated hydrocarbons which are chiefly responsible for the off-odors and off-flavors (Lea, 1962). The following reaction scheme illustrates scission and dismutation of hydroperoxide compounds to carbonyl and hydroxy compounds:



Lipids Responsible for Oxidation

Lea (1957) reported that bound lipids contribute to the reactions responsible for rancid odors and flavors in cooked meat. The reactivity of the lipid is influenced by the degree of unsaturation that makes up the particular lipid. Phospholipids from a particular tissue were also found to be more unsaturated than triglycerides from the same source. Hornstein et al., (1961) found that 19% of the fatty acids in beef phospholipids had four double bonds, whereas only 0.1% of the triglycerides showed the same degree of unsaturation. The presence of these highly unsaturated phospholipids renders the lipid more susceptible to oxidation. Younathan and Watts (1960) showed that proteolipids and phospholipid fractions contributed to the stale flavors in cooked rancid pork, whereas the triglyceride fraction did not. Campbell and Turkki (1967) found that neutral lipids were lost more readily during cooking than phospholipids. Hornstein et al., (1961) postulated that phospholipids were found in the bound form and would not be as easily lost during cooking.

Factors Influencing the Rate of Oxidation

The extent to which lipid oxidation occurs during refrigerated or frozen storage of meat and meat products is influenced by several factors. These factors include fat characteristics, the temperature at which it is stored, the packaging material, the storage period and the presence of either antioxidants or pro-oxidants, whether naturally present or added.

Catalysts in Meat Systems. Various types of compounds have been implicated as having catalytic effects in lipid oxidation. Tappel (1952,1953a) demonstrated that hematin compounds, such as hemoglobin, hemin and cytochromes are powerful catalysts at $0^{o}C$.

The valence state of the heme protein is important, with the ferric hemes being more active than the ferrous hemoproteins (Younathan and Watts, 1959). Fox (1966) reported that during cooking pigments are irreversibly converted to the denatured ferric chromogen, therefore acting as pro-oxidants in uncured meats. No significant increase in oxidative rancidity is noted in stored, cooked, cured meat as a result

of the pigment being present as the pink ferrous nitric oxide hemochromogen form.

Non-heme iron has also been implicated as pro-oxidants (Lui, 1970; Sato and Hegarty, 1971). Lui and Watts (1970) removed the metmyoglobin with hydrogen peroxide and significant lipid oxidation was noted without the metmyoglobin being present. Sato and Hegarty (1971) showed that non-heme iron accelerated the oxidation of lipids that had been extracted from cooked meat. Ferrous iron has been shown by Marcuse (1971) to have pro-oxidant ability. Sato and Hegarty (1971) also reported that ferrous iron, in the presence of a small quantity of ascorbic acid would act as potent lipid oxidation catalysts. Certain metal salts, such as cuprous and ferric salts, which act as catalysts at low levels, often exhibit inhibitory characteristics at higher levels (Marcuse and Fredriksson, 1971).

Sodium chloride is often an added ingredient to meat products, i.e. curing brines for hams. The oxidation accelerating effects of salt have been reviewed extensively in the literature (Watts, 1954; Dugan, 1961; Zipser et al., 1964; Love and Pearson, 1971).

Early studies cited an increase in lipid oxidation in raw refrigerated and frozen cured pork (Watts and Peng, 1947a; Watts and Pend, 1948). Chang and Watts (1950) reported that the amount of free moisture in the food system determined whether salt would increase or decrease lipid oxidation. They observed that 10% salt solutions inhibited lipid oxidation slightly, however, above 15% they noted an increase in oxidation. When equivalent concentrations of sodium chloride were brought into contact with fat over a wide surface area, much higher peroxide values were obtained with samples prepared by

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drying rather than in solution. Therefore, in food systems where salt and low free moisture are present, as in partially dried or frozen systems, an increase in lipid oxidation would be expected.

The mechanism by which salt increases the rate of lipid oxidation is not fully understood and the studies in the literature are often contradictory. Banks (1937) and Lea (1939) proposed a theory that salt was not a pro-oxidant but that it only promoted the activity of lipidoxidases. However, later studies by Banks (1944) and Tappel (1952,1953a) demonstrated that no lipidoxidase was present in the meat but rather the increase in autoxidation was due to the heme pigments, which are powerful catalysts of lipid oxidation. Hills and Conochie (1946) attributed the direct oxidative affect of the sodium chloride to the reactivity of the chloride ion. However, Watts and Peng (1947a) and Ellis _et al_., (1968) showed that various chlorides and halogens did not have the same affect as sodium chloride, thereby casting doubt on Hill's theory.

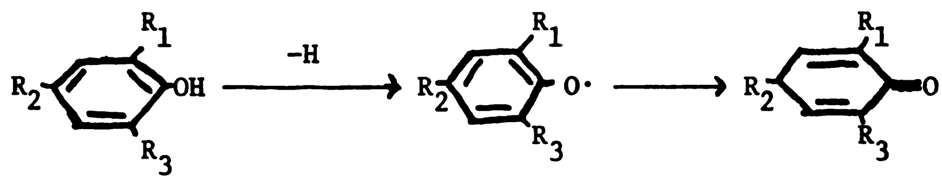
Younathan and Watts (1959) observed that oxidative reactions occured less readily in cured meats which retained their pink color. Sodium nitrite converts the pigments to the catalytically inactive ferrous nitric oxide. This results in a higher stability towards lipid oxidation under refrigeration conditions than with uncured cooked meat in which the pigment is present as ferric hemochromogen. As the cured meat pigment is slowly oxidized to the ferric form, a resulting increase in lipid oxidation would be expected. Salt has been shown to increase hematin oxidation to the ferric form, with or without fat present. Thus, the role of salt may be to oxidize the hematin to the ferric state, thereby initiating oxidation of nearby unsaturated lipids (Dugan, 1961).

Zipser *et al*., (1964) demonstrated that heme catalysis was stopped by the addition of nitrite, but that it was the sodium chloride that increased lipid oxidation of ham in the freezer. Heme catalysis and sodium chloride catalysis increased when nitrite was absent. Ellis *et al*., (1968) compared the effects of 0.03% sodium nitrite, 2.0% sodium chloride and a combination of the sodium chloride and sodium nitrite on the rate of lipid oxidation. They noted that trace amounts of sodium nitrite promoted lipid oxidation at a somewhat higher rate than that of the sodium chloride. The combination of sodium chloride and sodium nitrite promoted a faster rate of oxidation than the sodium chloride alone. There appeared to be an independent, yet additive effect of these two compounds on lipid oxidation. Ellis and co-workers proposed that these two compounds activated different catalytical systems, the mechanism of which remains unknown.

Antioxidants in Meat Systems. Antioxidants are substances that slow down the rate of lipid oxidation. The choice of the antioxidant is determined by the requirements of the systems and the characteristics of the antioxidant being used. The antioxidant should be effective at low concentrations, have no undesirable characteristics, be safe to handle and use and be low in cost. These compounds are generally aromatic compounds which are amine or phenolic in nature (Dugan, 1957).

Antioxidants terminate the free radical chain mechanism by any of the following ways: by donating an electron to the peroxy radical; by donating a hydrogen to the peroxy radical before or after being partially oxidized. An example of how a ring substituted phenol acts as a chain terminator can be illustrated as follows:

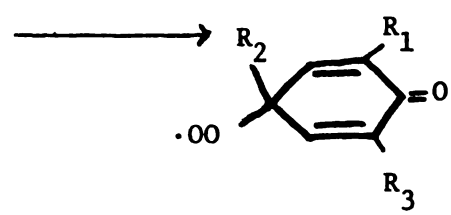
(a)



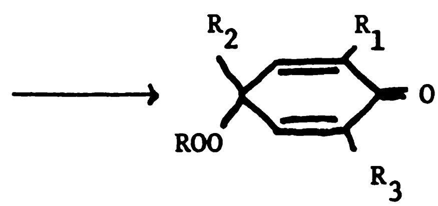
I II III

(b) 2 II ⟶ dimer

(c) III + O_2



(d) III + ROO



Termination will result if either (a), (b) or (d) occurs. However, if (c) occurs the phenol will react as a transfer agent without decreasing the overall rate of autoxidation. Most antioxidants have optimum levels at which they function but they can exert pro-oxidant effects by acting as transfer agents, as in (c) (Dugan, 1957).

Antioxidants that are often added to meat systems include n-propylene gallate (PG), butylated hydroxyanisol (BHA), and synergists, such as polyphosphates, citric acid and sodium ascorbate.

Lineweaver _et al._, (1952) and Klose _et al._, (1952) investigated the use of various antioxidants in frozen creamed turkey and frozen turkey, respectively. Neille and Page (1956) used various levels of monosodium glutamate, BHA and full fat soy flour in frozen ground pork.

Little difference was noted between the soy treated raw and cooked samples. There was no significant differences between the different levels of antioxidants used.

Naturally occuring antioxidants include the plant flavanoids and compounds produced during prolonged heating at high temperatures (Watts, 1962). Hot water extracts from various vegetable sources were reported to retard lipid oxidation in cooked meats (Ramsey and Watts, 1963). Researchers have attributed the antioxidant activity of various vegetable extracts to flavanoids and their ability to accept free radicals and break the chain reaction (Ramsey and Watts, 1963; Pratt and Watts, 1964). Pratt (1972) investigated the use of various soybean products. He noted potent antioxidant activity in lipid-aqueous systems and postulated that this ability was due to flavanoid components that occur naturally in soybeans.

Zipser and Watts (1961) reported that under prolonged heating, antioxidant substances were produced in uncured canned meats. Sato <u>et</u> <u>al</u>., (1973) noted that browning reaction produced which occured during the interaction of sugars and amino acids, inhibited the development of warmed-over flavor (WOF) in cooked ground beef. Reductic acid which is formed during browning reactions (Hodge, 1963) was found to be a very effective inhibitor. It was thought that this was due to its ascorbic acid type reaction. Maltol, produced from a Maillard type reaction, was also found to be an effective inhibitor, probably acting as a free radical inhibitor, however the exact mechanism in unknown. This study also investigated the use of various vegetable protein products (cottonseed, textured soy flour and textured vegetable protein) in ground beef. There was a noted decrease in the development of WOF during refrigeration, when these products were used. Sato and co-workers (1973) suggested that the inhibition of the development of WOF in these products was due to the production of antioxidant substances by the interaction of amino acids and carbohydrate upon heating. Vegetable soy protein products contain appreciable amounts of protein and carbohydrate (Rakosky, 1971), which would contribute to these browning reaction.

Measurement of Oxidative Rancidity

Watts (1954) and Dugan (1955) have reviewed the objective methods commonly used to determine the degree of oxidative rancidity that has occurred in foods, fats and oils. The most commonly used tests for determining the degree of rancidity are: The active oxygen method, determination of carbonyl compounds, peroxide values, which measures the degree of unsaturation and the 2-thiobarbituric acid test (TBA), which measures the amount of malonaldehyde.

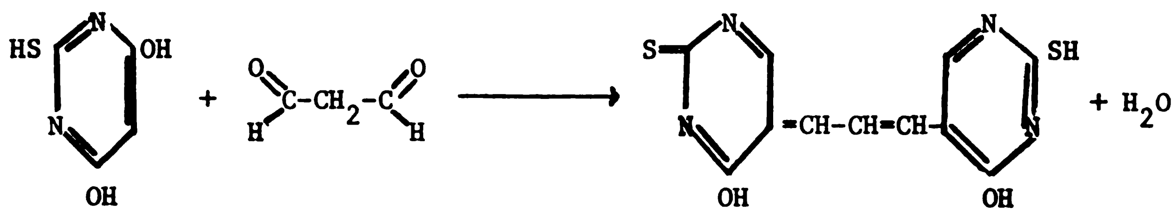
The majority of the tests for oxidative rancidity involve the extraction of the fat (mainly triglycerides) from meat tissues. However, the primary lipids involved with autoxidation and the development of rancidity are phospholipids and proteolipids (Younathan and Watts, 1960) which are not extracted by normal hydrocarbon solvents, but require more polar solvents such as methonol and ethanol (Lea, 1957). The TBA test has the advantage that the fat does not need to be separated from the other meat tissues. It would therefore be expected to measure the malonaldehyde produced from the autoxidation that has occurred in all of the lipid fractions. The TBA test also measures an end product of lipid autoxidation, malonaldehyde, while the peroxides are intermediate compounds of autoxidation which do not accumulate due to their rapid decomposition (Watts, 1954).

Malonaldehyde itself does not contribute to off-odors and flavors (Tarladgis et al., 1960). However these researchers did show a highly significant correlation between the TBA test and sensory evaluation of this rancid odor. Zipser et al., (1964) observed correlation of rancid odors and TBA values with cured and uncured pork. Kwon and Watts (1963) noted that the production of malonaldehyde was a useful indicator of flavor deterioration. The TBA test has been used to determine the degree of rancidity in a wide range of products which include dairy products, meats, fish, baked and cereal goods and fats and oils (Corliss, 1963).

Development of the TBA Test. Animal tissues, incubated aerobically, were found to produce a red color when reacted with 2-thiobarbituric acid (Kohn and Liversedge, 1944). They suggested an unidentified carbonyl compound was responsible for the color development. In 1947 Bernheim and co-workers postulated that the color was due to a product of oxidation from unsaturated fatty acids. Wilbur et al., (1949) observed the ability of various aldehydes and sugars to develop color and concluded that it was the result of a three carbon compound.

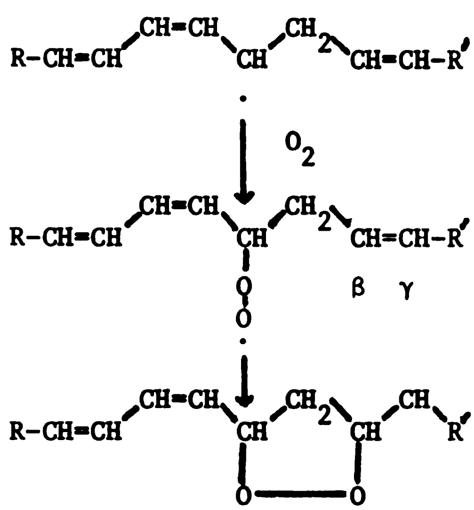
The compounds responsible for the Kreis color reaction test for rancid fats were thought to be the result of epihydrin aldehyde or its acetals (Powick, 1923). Patton and co-workers (1951) questioned this reasoning and found evidence that malonic dialdehyde was responsible for Kreis color reaction. Patton and Kurtz (1951) also demonstrated that malonic dialdehyde produced a red color when heated in the presence of 2-thiobarbituric acid.

Sinnhuber et al., (1958) proposed that the red pigment was a condensation product of two molecules of 2-thiobarbituric acid and one molecule of malonaldehyde with the elimination of two molecules of water, which can be illustrated as follows:

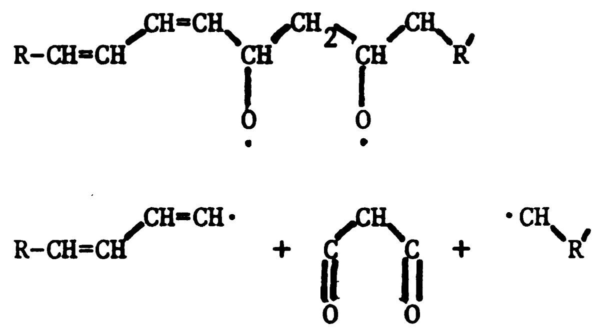


Upon acid hydrolysis 1,1,3,3-tetraethoxpropane (TEP) yields malonaldehyde. It was then possible to specify a "TBA Number" as mg of malonaldehyde per 1,000 g sample (Sinnhuber and Yu, 1958).

Dahle et al., (1962) proposed a mechanism of malonaldehyde formation from conjugated fatty acids with three or more double bonds. They theorized that with the β · γ unsaturated peroxide radicals, a 5 membered peroxide ring would be formed as shown in the following reactions:



The formation of malonaldehyde can then take place as follows:



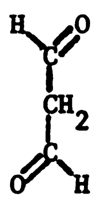
Lillard and Day (1964) reported the formation of malonaldehyde from the oxidation of various dienals, produced as result of oxidation of unsaturated fatty acids. There is then the possibility that malonaldehyde can be produced from autoxidation of polyunsaturated fatty acids and from the oxidation of secondary products of autoxidation.

There have been reported in the literature a number of different ways to perform TBA tests (Sidwell et al., 1954; Turner et al., 1954; Sinnhuber and Yu, 1958; Sunnhuber et al., 1958; Tarladgis, et al., 1960; Tarladgis et al., 1964; Marcuse and Johansson, 1973).

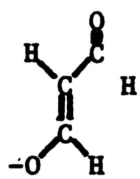
Sidwell et al., (1954) described a steam distillation method for dried milk, a fraction was then reacted with TBA and the color read directly. Turner and co-workers (1954) reacted pork with TBA in combination with trichloroacetic and phosphoric acid, the color was then extracted with an iso-amyl alcohol-pyridine mixture. Fishery products were heated with TBA in the presence of hydrochloric and trichloroacetic acids and pyridine, the color was then extracted with petroleum ether (Sinnhuber and Ye, 1958). Tarladgis et al., (1960) proposed a technique which used a distillation step which heated the sample directly rather than passing steam through it as had Sidwell's earlier method (Sidwell et al., 1954).

Tarladgis and co-workers later observed that the structure of TBA was altered upon acid-heat treatment (Tarladgis _et al._, 1964). They proposed a new technique which did not involve an acid-heat treatment but rather allowed the TBA and a sample of filtrate to stand for 15 hrs in the dark at room temperature. However, they noted that they were still not sure whether acid and heat were needed to release malonaldehyde from precursors in the oxidized product.

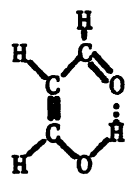
Kwon and Watts (1963) postulated that pre-formed malonaldehyde had reacted with other food components and would not be distillable. They proposed the term "distillable malonaldehyde" when using the TBA Number. Kwon and Watts (1964) observed malonaldehyde in aqueous solution and drew several conclusions. Malonaldehyde is capable of undergoing enolization from its diketo form (I) to its enolate anion (II) which is nonvolatile. It is also possible to form a volatile chelated form (III).



I



II



III

Approximately 96% of malonaldehyde is in the enolic form (II) in aqueous solution. These various tautomeric forms are very pH dependent, the enolic form (II) occurs at a pH>7, while the chelated form (III) occurs at a pH<3. Maximum volatilization of free-preformed malonaldehyde would therefore occur at a pH<3. Addition of acid is then necessary to free malonaldehyde from secondary combinations with other food constituents. The malonaldehyde in the enolate anion form might be stable against further irreversible reactions by formation of metal chelates from which the malonaldehyde can be recovered by acid and heat.

Other authors have reported the reaction of malonaldehyde with various other compounds, found in food systems. Brown (1962) showed a loss of malonaldehyde through its reaction with quanidine to form 2-aminopyrimidine, Kwon and Olcott (1965) observed interactions between proteins and malonaldehyde. Buttkus (1966) reported reaction between the amino acids of myosin and malonaldehyde. Crawford *et al*. (1966) and Chio and Tappel (1969a) reacted malonaldehyde with glycine to form an enamine.

EXPERIMENTAL PROCEDURE

Three ground meat systems, using 0% and 30% soy substitutions were investigated to observe differences in sensory evaluations, cooking losses, moisture, total lipid, phospholipid and neutral lipid content and development of oxidative rancidity during short term storage at refrigeration and freezing temperatures.

Preparation and Baking of Loaves

Formula

The basic formula used in this study was adapted from various recipes which were investigated during preliminary research. Table 1 lists the formulas used for the three ground meat systems.

All of the ingredients were purchased in common lots. The soy product was an unflavored spun vegetable protein.[1] Turkey was ground from thighs containing a natural proportion of skin, and purchased from a Michigan poultry processor. Pullman hams, ground pork and ground beef (20% fat) were obtained from the Michigan State University Food Stores.

Method of Preparation

Enough meatloaf mixture of each variable was prepared for five replications. The ham and turkey thighs were ground separately through

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[1]Temptein, Miles Laboratories, Elkhart, Indiana.

a Hobart Food Cutter, Model 84181D, using a 3/16 in plate. The textured soy protein was rehydrated in cold water for 5 min. The ground meat and rehydrated textured soy was then mixed for approximately 1 min in a Hobart Mixer, Model K-200, in order to thoroughly mix the two ingredients. The remaining incredients were divided into thirds, each portion was then added separately and mixed into the meat for approximately 30 sec. Finally both the 0% and 30% soy substituted meatloaf mixtures were then reground through the Hobart Food Cutter to insure uniformity.

Table 1. Amount of ingredients (grams) used in the preparation of 0% and 30% soy substituted ground meat systems.

Ingredient	Meat system		
	Beef	Turkey	Pork[a]
Ground meat[b]	1703	1703	1703
Bread Crumbs	207	207	207
Dried Onions	38	38	38
Salt	10	10	10
Poultry Seasoning		10	
Bar-B-Q Sauce	75		
Catsup	187		

[a]A 50:50 mixture of ham and pork was used.

[b]For the 30% soy substituted loaves 1192 g of ground meat was used in addition to 170 g of textured soy protein and 340 g of cold water.

Approximately 1500 g of meatloaf mixture was placed in a 10 x 4 x 3½-in Ham Loaf Press and held under pressure for 5 min in order to obtain loaves of the same degree of compactness. Each loaf was then wrapped first in Reynolon Food Service Film, rewrapped in aluminum foil and stored at -11°C for periods up to 5 weeks. The loaves were removed from the freezer and thawed at 5°C for 14 hrs prior to baking.

Since ham is susceptible to increased rancidity upon freezing, the pork loaves were prepared on the day of baking from ground pork purchased in a common lot and frozen at -11°C and ham which was held at 5°C. The procedure was the same as the beef and turkey, except that a Kitchen Aid Mixer, Model K-5A was used to mix the ingredients.

Baking

The 0% and 30% soy substituted loaves were randomly assigned as two preparations for any one "baking" day. The loaves, which were supported on racks in 9 x 12-in baking pans lined with aluminum foil, were baked in a General Electric, 30-in compact oven Model CN 16, with the damper half closed and the grid set at medium. The oven temperature was maintained at 177 ± 1°C by a Versatronik controller. Loaves were baked to an internal temperature of 77°C, which was determined by an iron constantan thermocouple lead inserted in the center of the loaf. Upon removal from the ovens the loaves were allowed to stand for 5 min before total, volatile and drip losses were determined according to the method outlined by Funk *et al.*, (1966).

Division of Loaves for Analyses

The middle third of each loaf was used for sensory evaluation. The end slices were removed and discarded. Three consecutive ½-in slices were taken from each end portion for the 2-thiobarbituric acid tests. These slices were then wrapped in aluminum foil and samples were stored at either 5°C for 0, 2 and 4 days or -11°C for 1, 2 and 3 weeks. Assignment of slices was rotated so that each slice was used the same number of times for the TBA determinations at any one temperature and storage time. The remaining loaf was ground, mixed thoroughly and used for moisture and lipid analyses.

Analyses

Sensory

Samples were assigned random numbers and served warm to an 11-member trained taste panel. Taste panel members were trained so that they could correctly identify samples containing soy protein in paired comparison. Beef and turkey were used to familarize the panel members with the score card. Preliminary research, which compared 0%, 15% and 30% soy substituted ground beef, showed that there were no significant differences between quality characteristics of exterior color, interior appearance, and interior color. (See appendix). Since significant differences occurred for flavor, juiciness, mouthfeel and over-all acceptability scores, these four quality characteristics were evaluated in the present study using a descriptive score card, with scores of 7 being optimum. (See appendix).

Chemical

Duplicate determinations were made for each analysis. Raw and cooked ground meatloaf mixtures were used for all analyses except for the TBA determinations, which were carried out on cooked samples only. Methanol and chloroform were glass distilled. The acetic acid for the TBA determinations was refluxed with 2 g TBA/100 ml acetic acid for three hrs and then distilled.

Moisture analysis. Moisture in the raw and cooked meatloaf mixtures was determined by drying 2 g samples, weighed to the nearest 0.001 g, for 6 hrs at 90°C and under a vacuum of 27-in of Hg and reweighed following cooling. Percentage moisture in each sample was calculated according to the following formula,

$$\% \text{ moisture} = \frac{\text{wt of moisture lost (g)}}{\text{wt of original sample (g)}} \times 100$$

Total Lipid Extraction. The total lipid extraction was carried out using modifications of the procedure described by Bligh and Dyer (1959). To maintain solvent relationships, 34 and 50 ml of distilled water were added to 66 g samples of raw and cooked meatloaf mixtures, respectively. Meatloaf samples were weighed to the nearest 0.001 g, combined with appropriate water and blended with 100 ml of chloroform and 200 ml of methanol in a Waring blender, attached to a powerstat to reduce line voltage to 55 volts. An additional 100 ml of chloroform and 100 ml of distilled water were then added separately and the samples blended 3 min after each of these additions.

The extract was filtered through a Coors No. 3 Buchner funnel, lined with Whatman No. 1 filter paper, by the use of slight vacuum.

The blender, residue and funnel were rinsed with 5 - 10 ml aliquots of chloroform and methanol, these washings were then added to the filtered extract. The filtered extract was then placed in a 500 ml separatory funnel; the side arm flask was rinsed with 5-10 ml aliquots of chloroform and methanol and added to the separatory funnel. The lipid-containing chloroform layer was then transferred to a 250 ml volumetric flask, and brought to volume with additional chloroform. Ten milliliter aliquots of fat extract were pipetted into dried preweighed 50 ml erlenmeyre flasks and the chloroform evaporated under nitrogen. The percentage lipid, on a wet weight basis was calculated based on the weight of the lipid content of the aliquot, according to the following formula.

$$\% \text{ lipid} = \frac{\text{wt of lipid (g)/10 ml} \times 25}{\text{wt of sample (g)}} \times 100$$

In order to compare raw and cooked percentage lipid values, the lipid percentages on a wet weight basis were converted to percentages of lipid on a dry weight basis by the following formula.

$$\% \text{ lipid (dry wt)} = \frac{\% \text{ lipid (wet wt)}}{\% \text{ solids}} \times 100$$

Separation of Neutral Lipid and Phospholipid. The total lipid fraction was separated into neutral lipid and phospholipid fractions using modifications of the procedure described by Choudhury et al., (1960). This involved a separation on activated silicic acid, in which the neutral lipids were removed by washing with chloroform, followed by removal of phospholipid with methanol.

Silicic acid was activated by drying silicic acid in a 100°C oven for 16 hrs. A slurry was prepared by the addition of chloroform to a 5 g activated silicic acid and a 10 ml aliquot of lipid extract in a 250 ml beaker. This slurry was allowed to stand for 30 min at room temperature. The slurry was then transferred to a 150 ml 60-M Buchner funnel fitted with a fritted disk and then washed with 300-400 ml of chloroform using slight vacuum. The remaining phospholipid containing silicic acid was then washed with 200-300 ml methanol. Each solvent was then decanted into a 500 ml round bottom flask with 5-10 ml aliquots of the appropriate solvent which was used to wash the side arm flask. A Rotovapor was used to reduce the volume of solvent to 5-10 ml which was then decanted into a dried, preweighed 50 ml erlenmeyer flask. The remaining solvent was then evaporated to dryness using nitrogen. Final traces of solvent were removed by placing the flasks in a 100^{o}C oven for 5 min. Percentages of neutral lipids and phospholipids in the total lipid sample were calculated according to the following formulas.

$$\%\ \text{neutral lipid} = \frac{\text{wt of neutral lipid (g)/10 ml}}{\text{wt of total lipid (g)/10ml}} \times 100$$

$$\%\ \text{phospholipid} = \frac{\text{wt of phospholipid (g)/10 ml}}{\text{wt of total lipid (g)/10 ml}} \times 100$$

<u>2-Thiobarbituric Acid Determination for Turkey and Beef</u>. The TBA method employed was similar to the distillation method as outlined by Tarladgis <u>et</u> <u>al</u>.,(1960). TBA determinations were done on cooked samples which had been stored for 0, 2 and 4 days at 5^{o}C and 1, 2 and 3 weeks at -11^{o}C. The frozen slices were thawed for 14 hrs at 5^{o}C before being analyzed. Each slice was ground before duplicate samples were taken. A 10 g sample was blended for 2 min with 50 ml of distilled water in a Waring blender at low speed. The mixture was

then quantitatively transferred to a 500 ml round bottom flask with 47.5 ml distilled water. The pH was lowered to 1.5 by adding 2.5 ml of HCl (2:1). A small amount of Dow antifoam was sprayed into the flask to prevent foaming. The distillation apparatus consisted of the flask connected to a 300 mm Vigreaux distillation column, which was attached to a Leibig condensor. Heating mantles were used to distill the mixture as rapidly as possible. After 50 ml of the distillate were collected in a 100 ml graduated cylinder, it was stoppered and the mixture inverted several times. Five milliliters of the distillate were then pipetted into a 50 ml glass-stoppered test tube and 5 ml of 0.02 M TBA in 90% acetic acid were added. The contents were gently mixed before boiling and placed in a boiling water bath for 35 min, then tubes were placed in a cold water bath for 10 min. A sample from the tube was read on a DB Spectrophotometer against a blank at a wavelength of 532 nm. The % T was converted to absorbance by Iscotables (Iscotables, 1972).

In order to determine the distillation constant to obtain the "TBA Number", a standard curve and percentage recoveries were obtained. Dilutions (3×10^{-8}M, 1×10^{-8}M, 9×10^{-9}M, and 7×10^{-9}M) of 1,1,3,3-tetraethoxypropane (TEP), which yield malonaldehyde on acid hydrolysis, were used to obtain a standard curve. The TEP dilutions were used to replace the 5 ml of distillate and the procedure was continued as previously outlined. The percentage recovery in all systems was obtained by adding 5 ml of 3×10^{-8}M TEP to the sample before distillation and determining the amount recovered. Recovery was calculated to be 70%.

Two different ways have been presented in the literature to calculate the distillation constant (k). Tarladgis *et al.*, (1960) used the following formula.

$$k = \frac{\text{conc in moles/5 ml distillate}}{\text{O.D. (absorbance)}} \times \text{M.W. of malonaldehyde} \times \frac{10^7}{\text{wt of sample}} \times \frac{100}{\text{\% recovery}}$$

Witte *et al.*, (1970) however included the consideration of sample equivalent and their formula is as follows:

$$k = \frac{S}{A} \times MW \times 10^6 \times \frac{100}{P}$$

where: S = conc in moles/5 ml distillate (1×10^{-8})
A = absorbance (0.146)
MW = molecular weight of malonaldehyde
E = sample equivalent (10 g/100 ml x 5 ml = 0.5)
P = % recovery

"TBA Numbers" were calculated according to the distillation constant as determined by Witte's method and reported as mg of malonaldehyde per 1000 g of sample.

Modification of the TBA Method for Ham. According to Zipser and Watts (1962) small amounts of nitrite are capable of significantly reducing TBA numbers of rancid meat. This interference occurs in the distillation step of the TBA procedure and it believed to be due to nitrosation of malonaldehyde. Sulfanilamide is used to bind the nitrite to form a diazonium salt. Since the pork mixture contained 50% ham, a determination of the amount of nitrite present was made. Ten grams of meatloaf mixture were ground with 50 ml of double distilled water for 1 min. This mixture was centrifuged for 5 min at 15000 rpm.

Ten milliliters of supernatant were pipetted into an evaporating dish containing 10 ml of a 1:1 mixture of 1% sulfanilic acid in 30% acetic acid and 0.1% napthylamine in 30% acetic acid. The red color that developed was compared to standards of $NaNO_2$ ranging from 50 ppm to 200 ppm. The 10 g sample of ham loaf contained less than 100 ppm nitrate, which according to Zipser and Watts (1962) was a "mild" test. The only modification necessary to make was to use 1 ml of 0.5% sulfanilamide and 49 ml of distilled water, which was ground with the 10 g sample of meat and the procedure was then continued as previously described for turkey and beef.

Statistical

Analyses of variance between 0% and 30% soy substitutions were calculated by a Wang 600 computer for the following factors: sensory evaluations of flavor, juiciness, mouthfeel and overall acceptability; and total, drip and volatile losses. Analyses of variance between 0% and 30% soy substitutions and raw and cooked states were calculated by a Digital Computer, Model PDP-11/40RSTS for the following factors: total lipid; moisture; phospholipid and neutral lipid; and TBA values for the two storage periods of $5^{o}C$ and $-11^{o}C$. Duncan's Multiple Range Test (1957) was used to sort out significant differences revealed by analysis of variance.

RESULTS AND DISCUSSION

Ground beef, pork and turkey meat systems, using 0% and 30% soy substitutions were prepared. Sensory evaluations, cooking losses and determination of the rates of oxidative rancidity, during short term storage at $5^{o}C$ and $-11^{o}C$, were determined on the cooked loaves. The percentage moisture, total lipid, phospholipid and neutral lipid content were determined for both the raw and cooked loaves.

Cooking losses

Total cooking losses were determined by measuring weight changes between raw and cooked meats. Drip losses were designated as the material that accumulated in the pan during cooking and volatile losses were calculated as the difference between the total cooking losses and drip losses. Total, drip and volatile cooking losses are presented in Table 2, whereas summaries of analyses of variance for cooking losses are presented in Table 2, whereas summaries of analyses of variance for cooking losses are presented in Table 3.

The 0% soy substituted beef loaves had a 13.3% total cooking loss, whereas the 30% soy substituted beef had a significant ($p<0.05$) lower cooking loss of only 9.8%. Analyses of variance established a very high significant difference in the amount of drip loss between the 0% and 30% soy substituted beef. There were however, no significant differences between the volatile losses of the two systems.

Table 2. Means and standard deviations of total cooking loss (%), drip loss (%) and volatile loss (%) of soy substituted meat systems.

Meat System	% Soy	Cooking Losses		
		Total	Drip	Volatile
Beef	0	13.3±1.4[a]	2.9±0.3	10.4±1.2
	30	9.8±1.8	0.4±0.1	9.4±1.7
Pork	0	15.8±1.4	5.9±1.4	10.0±0.2
	30	12.2±2.3	0.4±0.1	11.8±2.1
Turkey	0	16.6±0.7	0.5±0.1	16.0±0.7
	30	15.6±1.5	0.1±0.1	15.5±1.5

[a]Based on 5 replications

Table 3. Analyses of variance of total cooking loss, drip loss and volatile loss of soy substituted meat systems.

Meat System	Source	df	Mean Squares		
			Total	Drip	Volatile
	Total	9			
Beef	Soy	1	29.241*	15.376***	2.304
	Within	8	2.683	0.068	2.156
	Total	9			
Pork	Soy	1	32.400**	73.984***	8.281
	Within	8	3.642	1.488	2.281
	Total	9			
Turkey	Soy	1	1.307	0.327*	0.375
	Within	8	0.689	0.033	0.742

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

Analysis of variance showed that total cooking losses of 15.8% for the 0% soy substituted pork was significantly higher ($p < 0.01$) than that of 12.2% for the 30% soy substituted pork. Drip losses of 5.9% and 0.4% were calculated for 0% and 30% soy substituted pork, respectively; these differences were very highly significant ($p < 0.001$). The volatile losses were not significantly different.

Total and volatile losses were not significantly different for the turkey meat systems. Significant ($p < 0.05$) differences were noted between the drip losses of 0.6% and 0.1% for the 0% and 30% soy sbustituted turkey, respectively.

Drip losses consists of fat that has melted out during the cooking process whereas volatile losses are a result of the evaporation of water and other volatile compounds (Paul and Palmer, 1972). Since two of the important functional properties of soy proteins are its ability to bind fat and its ability to retain moisture (Wolf, 1970), it would be expected that the incorporation of texturized soy protein would result in a decrease in total cooking losses, a subsequent decrease in cooking drip and a possible decrease in volatile losses. Soy substitutions decreased cooking losses in both beef and pork systems whereas it decreased drip loss in all three systems. There were no significant differences in the volatile losses between the levels of soy in any of the soy substituted meat systems.

Sensory Evaluation

An 11-member, trained taste panel evaluated the 0% and 30% soy substituted meat systems for the quality characteristics of flavor, juiciness, mouthfeel and overall acceptability, using a 1-7 descriptive score card, with 7 being optimum. The sensory taste panel results are presented in Table 4, and the analyses of variance to determine significant differences are presented in Table 5.

Although the non-soy substituted meat loaves scored slightly higher, all of the flavor scores for beef and turkey systems were from 5.3 to 6.0 and were not significantly different. The 0% and 30% soy substituted pork loaves did differ significantly ($p < 0.01$) with respect to flavor, with scores of 6.4 and 4.6, respectively. The significant difference for the pork system may be due to the formulation, since pork systems did not contain any additional flavorings, such as tomato in the beef system or poultry seasoning in the turkey system, to mask the "off"-flavor that is reported to be associated with soy. Descriptive terms used by the panelists indicated 30% of the soy substituted pork loaves had off-flavors whereas only 3% of the 0% soy substituted pork flavor scores indicated a presence of an "off"-flavor.

The 0% soy substituted beef and turkey systems scored slightly higher for juiciness than the 30% soy substituted loaves, although these differences were not significant. There were highly significant differences ($p<0.01$) in juiciness between the 0% and 30% soy substituted pork systems. The taste panelists scored on both loaves as being slightly dry with over 56% of the responses indicating that the non-soy substituted loaves were dry, whereas 83% thought the 30% soy substituted pork was dry.

Juiciness is a very complex sensation and several factors must be considered. Not only is the amount of moisture important but also the amount of fat present and the availability of the fat to be sensed

Table 4. Means and standard deviations of sensory evaluations of soy substituted meat systems.[a]

Meat system	% Soy	Sensory Evaluation			
		Flavor	Juiciness	Mouthfeel	Overall
Beef	0	5.7±0.2[b]	5.6±0.3	5.6±0.3	5.6±0.3
	30	5.3±0.8	5.2±0.2	5.1±0.5	4.6±0.7
Pork	0	6.4±0.2	5.9±0.4	6.0±0.2	5.8±0.3
	30	4.6±1.1	4.8±0.5	5.2±0.9	4.1±1.0
Turkey	0	6.0±0.4	5.6±0.2	5.7±0.2	5.3±0.5
	30	5.3±0.6	5.5±0.3	5.8±0.5	4.7±0.5

[a]Scale of 1-7, with 7 being optimum.

[b]Based on 5 replications.

Table 5. Analyses of variance of sensory evaluations of soy substituted meat systems.

Meat System	Source	df	Mean Square			
			Flavor	Juiciness	Mouthfeel	Overall
	Total	9				
Beef	Soy	1	0.256	0.256	0.625	0.484
	Within	8	0.323	0.071	0.168	0.306
	Total	9				
Pork	Soy	1	7.744**	2.740**	1.681	6.724**
	Within	8	0.681	0.220	0.477	0.462
	Total	9				
Turkey	Soy	1	1.089	0.036	0.025	0.961
	Within	8	0.269	0.068	0.175	0.266

**Significant at the 1% level of probability.

in the mouth when evaluating the product for juiciness. For the cooked 0% and 30% soy substituted pork there were no significant differences between the amount of fat present (Table 8) nor the amount of moisture present (Table 6) in either of the cooked pork systems, therefore it is speculated that the soy binds the fat in such a way that it does not promote a sense of juiciness, which would explain the lower scores in all of the 30% soy substituted systems.

Mouthfeel is a very difficult sensation to evaluate. The term "pebbly" was used to describe the optimum mouthfeel of a ground meat system. No significant differences were found between mouthfeel of the 0% and 30% levels of soy in any of the meat systems. Unless there are extremes to evaluate, such as very mushy as compared to very gritty, it is hard to distinguish the varying degrees in between the two extremes.

Evaluation for overall acceptability indicated that there were no significant differences between the 0% and 30% levels of soy in the beef and turkey systems. This can be explained by the fact that the textures soy protein products have been engineered to be substituted into ground meat systems, in particular ground beef, so as not to change the textural appearance, mouthfeel, juiciness or flavor of these systems (Rakosky, 1974). The textured soy protein, Temptein "Meat-Like Nuggets" used in this study were unflavored and colored dark brown, so when rehydrated they blended in quite well with the ground beef and ground turkey thighs, without significantly changing the overall appearance. There was however, a highly significant difference ($p<0.01$) in the overall acceptability of the soy substituted pork systems, with the 0% soy substituted loaf receiving a score of 5.8

and the 30% soy substituted loaf receiving 4.1. A major contributing factor for the lower scores for the 30% soy substituted pork loaves might have been the difference in color of the loaves, with the 0% soy substituted loaf being pinker in color, which is more characteristic of a "ham" loaf.

Moisture

The percentage moistures for the three meat systems are presented in Table 6, and analyses of variance to determine significant differences are presented in Table 7. Significant differences among levels of soy and state of meat (raw or cooked) were pinpointed using Duncan's Multiple Range Test (1957).

Table 6. Mean values and standard deviations of percentage moisture of raw and cooked soy substituted meat system.

Meat System	% Soy	State	
		Raw	Cooked
Beef	0	58.4 ± 1.0[a]	54.4 ± 1.6
	30	58.7 ± 0.6	53.1 ± 1.5
Pork	0	54.9 ± 1.4	53.6 ± 1.8
	30	57.3 ± 1.0	52.1 ± 1.5
Turkey	0	62.9 ± 0.9	57.4 ± 0.8
	30	61.8 ± 0.6	55.7 ± 0.4

[a]Based on 5 replications.

Table 7. Analyses of variance of percentage moisture of raw and cooked soy substituted meat systems.

Source	df	Mean Square		
		Beef	Pork	Turkey
Total	19			
Soy	1	1.250	5.508	9.382***
State	1	115.199***	36.176**	169.945***
Inter-action	1	3.039	9.660	0.547
Within	16	1.554	3.702	0.464

**Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

Cooked beef loaves had significantly less ($p<0.001$) moisture than did the raw loaves but no significant differences were noted between the raw 0% and 30% soy substituted beef loaves nor between the cooked 0% and 30% soy substituted beef systems. Non-soy substituted beef loaves retained more moisture (93.1%) than did the soy substituted beef (90.5%).

Analysis of variance showed significant differences ($p<0.01$) between the raw and cooked state of the 0% and 30% soy substituted pork systems. Using Duncan's Multiple Range Test no significant difference was noted between raw and cooked 0% soy substituted pork, however a very highly significant difference was noted between the raw and cooked 30% soy sbustituted pork. The percentage moisture retained by the 0% soy substituted pork was 97.6%, while the 30% soy substituted loaf retained only 90.0% moisture.

Very highly significant differences were noted among the levels of soy and the raw and cooked state of the turkey loaves. Duncan's Multiple Range Test showed very highly significant differences between the raw and cooked states of both the 0% and 30% soy substituted turkey systems. Significant differences ($p<0.05$) were also noted between the raw 0% and 30% soy substituted turkey. Moisture retention in both the raw and cooked turkey systems were quite similar, i.e. 91.3% and 90.1% for 0% and 30% soy substituted systems, respectively.

A decrease in the moisture content from the raw to the cooked state would be expected due to the denaturation and coagulation of the proteins which would lessen the water holding capacity of the tissue. The free water would be squeezed out as the structure shrinks and when heated in a dry atmosphere, most of the water would evaporate, forming the major portion of volatile losses. Volatile losses are related to the amount of moisture lost during cooking, therefore, it would be expected that since there was no significant difference in moisture between the cooked 0% and 30% soy substituted beef and pork systems, no significant difference would be noted between volatile losses. There was however, a significant difference ($p<0.001$) between percentage moisture in the 0% and 30% soy substituted cooked turkey systems; however, no significant difference between the volatile losses of the 0% and 30% soy substituted turkey systems.

Soy proteins are hydrophilic and would therefore be expected to absorb and retain water (Wolf, 1970). During the preparation of the soy for incorporation into the meat systems, the soy absorbed two times its weight in water. However, the results from this study indicate that the 30% soy substituted meat systems did not retain as much water as the 0% soy substituted systems, however the only significant difference occurred in the ground turkey system.

Two studies were found in the literature which compared moisture contents of non-soy and soy substituted meat systems. Carlin and Nielson (1974) reported the use of 30% textured soy protein in ground beef loaves. Both the 0% and 30% soy substituted beef loaves were analyzed for moisture in the raw systems and in subsequently reheated loaves. They noted the raw percentage moisture for 0% and 30% soy substituted beef to be 62.2% and 63.8%, respectively. However, the percentage moisture for the 0% soy substituted beef increased to 64.2% upon reheating and the 30% soy substituted beef decreased to 61.6%. Brant (1972) analyzed 0% and 27% substituted beef patties (raw and cooked) for moisture. In the raw state the 0% soy substituted beef contained 57.4% moisture while the raw 27% soy substituted beef contained 55.5% moisture. Upon cooking the 27% soy substituted beef decreased to 54.9% or retained 93.7% moisture. However, due to "insufficient sample" the 0% soy substituted cooked beef were not analyzed. No substantial evidence was found to support or contradict the findings of these studies.

Total Lipids

A chloroform methanol extraction was used to determine the percentage of total lipid in the three meat systems. Lipids were calculated on a dry weight basis in order to compare raw and cooked lipids. The values for total, phospholipid and neutral lipid are presented in Table 8, and analyses of variance to determine significant differences among these lipid values are given in Table 9.

The total lipid values for the 0% soy substituted beef decreased from 25.2% to 17.5% upon cooking, retaining 69.4% of the fat; whereas the 30% soy substituted beef retained 88.2% fat, decreasing only from 17.8% to 15.7% as a result of cooking. Analysis of variance showed very highly significant differences between both the levels of soy and the raw and cooked state, with a highly significant $p<0.01$) interaction occuring. Duncan's Multiple Range Test demonstrated that there was a significant ($p<0.001$) difference between raw 0% and 30% soy substituted loaves as would be expected since up to 30% of the total fat was replaced by 30% rehydrated soy, which contained less than 1% fat. No significant differences were noted between the cooked 0% and 30% soy substituted beef. A very highly significant difference was noted between the raw and cooked 0% soy substituted

Table 8. Means and standard deviations of total lipid (%)[a], phospholipid (%)[b] and neutral lipid (%)[b] of raw and cooked soy substituted meat systems.

Meat System	State	% Soy			% Soy		
		Total	Phospholipid	Neutral	Total	Phospholipid	Neutral
Beef	Raw	25.5±1.8[c]	4.0±1.0	94.9±1.4	17.8±0.5	5.5±0.9	93.6±1.3
	Cooked	17.5±2.3	6.6±0.8	92.9±2.2	15.7±1.6	5.8±2.0	93.0±1.6
Pork	Raw	30.7±2.4	3.9±1.0	97.9±3.8	22.2±4.4	5.3±0.6	94.9±3.5
	Cooked	21.8±1.7	6.5±1.1	96.5±3.8	19.7±1.0	6.6±1.0	94.6±1.4
Turkey	Raw	20.3±0.9	8.1±0.3	92.7±0.8	13.1±0.5	11.0±1.4	91.6±2.6
	Cooked	17.9±3.2	6.5±1.4	65.9±15.9	12.8±1.4	8.1±1.5	91.4±2.5

[a]Calculated on a dry weight basis.

[b]Based on percentage of total lipid.

[c]Based on 5 replications.

Table 9. Analyses of variance of total lipid, phospholipid and neutral lipid of soy substituted meat systems.

Meat System	Source	df	Mean Squares		
			Total	Phospholipid	Neutral
	Total	19			
	Soy	1	107.185***	0.612	1.859
Beef	State	1	123.504***	11.401	8.312
	Interaction	1	37.812**	6.613	2.516
	Within	16	2.782	1.505	2.808
	Total	19			
	Soy	1	139.921***	2.644	49.609*
Pork	State	1	165.312***	19.013***	0.047
	Interaction	1	51.520**	1.860	8.594
	Within	16	3.411	0.875	10.817
	Total	19			
	Soy	1	181.202***	24.860***	740.545**
Turkey	State	1	10.951	25.765***	912.520**
	Interaction	1	4.232	2.115	1062.080**
	Within	16	3.240	1.583	66.380

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

beef, however no signifciant decrease in raw and cooked lipids was found in the 30% soy substituted beef.

Raw 0% soy substituted pork decreased from 30.7% total lipid to 21.8% upon cooking, retaining 71% total lipid. The 30% soy substituted pork decreased from 22.2% to 19.7% total lipid upon cooking, retaining 88.7% total lipid. Very highly significant differences ($p<0.001$) between levels of soy and the raw and cooked states were determined by analysis of variance and the differences evaluated according to Duncan's Multiple Range Test. Significant differences ($p<0.001$) in total lipids were found between raw 0% and 30% substituted pork loaves. No significant differences, however, were observed between the cooked 0% and 30% soy substituted pork or the 30% soy substituted raw and cooked pork systems. Nevertheless, raw non-soy substituted loaves contained significantly ($p<0.001$) more lipid than the cooked non-soy substituted loaves.

The percentage fat retained for the 0% and 30% soy substituted turkey were 88.2% and 97.7%, respectively. Soy substituted systems had significantly less ($p<0.001$) fat than did the non-soy substituted loaf. There was a very highly significant difference between the raw 0% and 30% soy substituted turkey. No significant differences however, occurred as a result of cooking.

An important functional property of soy protein is its ability to bind fat (Wofl, 1970). It would therefore be expected that products containing soy would retain more fat than a 0% soy substituted meat system, as shown by the results in this study. As a result of the large amount of fat retained, cooking drip exhibited the expected decrease with the increased level of soy (Table 3).

The total lipids for the 0% soy substituted soy beef loaves were higher than those reported by Campbell and Turkki (1967) for raw and cooked ground beef muscle. This may be explained by the fact that ground beef has adipose tissue included, whereas the beef muscles did not. The values reported in this study for raw and cooked percentage total lipids for the 0% soy substituted pork loaves are similar to the values reported by Campbell and Turkki (1967) for ground pork.

The trend for increased fat retention in soy substituted meat systems is substantiated by reports in the literature. Carlin and Nielson (1974) reported a 94% retention of fat upon reheating with the use of 30% soy substituted beef as compared to only 65% fat retention upon reheating of the 0% soy substituted beef patties. Brant (1974) reported a 79% fat retention with the use of 27% textured soy protein beef patties, again however, due to "insufficient sample" the cooked 0% soy substituted beef patties were not analyzed. Although the addition of soy diluted the fat in the raw state, soy retained the fat better, therefore the levels of fat in the cooked loaves was essentially the same, so that soy substitution in the meat loaves would not result in a decrease in calories.

Phospholipid and Neutral Lipid

Percentages of phospholipid and neutral lipids were determined by using a separation on silicic acid by washing with chloroform and methanol. Percentages for these values were determined on the total weight of the lipid (Table 8).

As a result of cooking the relative concentration of phospholipid in the 0% and 30% soy substituted beef increased from 4.0% to 6.6% and from 5.5% to 5.8%, respectively. Analysis of variance

(Table 9) revealed that there was a significant difference ($p<0.05$) between the raw and cooked state. Duncan't Multiple Range Test pinpointed this difference to be a significant ($p<0.05$) increase in the 0% soy substituted beef phospholipid as a result of cooking. No significant differences between 0% and 30% soy substituted raw and cooked beef phospholipid or between 30% soy substituted raw and cooked beef phospholipid were noted. There were no significant differences between the neutral lipids in either the level of soy or the raw and cooked state of the beef loaves.

The percentage phospholipids increased with cooking from 3.9% to 6.5% for the 0% soy substituted pork systems and from 5.3% to 6.6% for the 30% soy substituted pork systems. Significant differences ($p<0.05$) between the raw and cooked states of the 30% soy substituted pork systems, and very highly significant differences between raw and cooked 0% soy substituted pork were indicated by Duncan's Multiple Range Test. Significant differences ($p<0.05$) were noted between raw 0% and 30% soy substituted pork, while no significant differences were found between the cooked 0% and 30% soy substituted pork loaves. A significant difference did occur between the 0% and 30% soy substituted pork neutral lipids in the raw state, however no significant change was found as a result of cooking for either the 0% or 30% soy substituted pork systems.

The percentage phospholipids decreased during cooking from 8.1% to 6.5% for the 0% soy substituted turkey systems and a similar decrease occurred with the 30% soy substituted turkey, decreasing from 11.0% to 8.1%. Highly significant differences were found between the raw 0% and 30% soy substituted turkey system, with no significant differences occuring between the cooked 0% and 30% soy substituted turkey loaves. A significant decrease ($p<0.01$) in phospholipid content occurred as a result of cooking with the 30% soy substituted turkey system, while cooking did not cause a significant decrease in the percentage of phospholipid in the % soy substituted turkey system. A very highly significant decrease was observed in the neutral lipid content of the raw and cooked 0% soy substituted turkey as a result of cooking, decreasing from 92.7% to 65.9%. No significant difference was found between the raw and cooked 30% soy substituted turkey. No significant difference was observed between the raw 0% and 30% soy substituted turkey systems, however very highly significant differences did occur between the cooked 0% and 30% soy substituted turkey loaves.

Relative increase in the phospholipid content occurred in both the 0% and 30% soy substituted beef and pork systems as a result of cooking. These results are consistent with those reported by Campbell and Turkki (1967) for ground beef and pork. This increase has been attributed to the fact that phospholipids are an integral part of the muscle cell and are closely associated with the protein (Campbell and Turkki, 1967; Lea, 1957). The neutral lipids however, are inter-cellular and are more readily rendered from by the tissue during cooking than are the phospholipids.

The decrease, rather than the increase, in phospholipid content in the cooked turkey systems is rather difficult to explain. Lee (1972) reported a decrease in the phospholipid content of chicken as a result of frying in corn oil, however no explanation was given. Decreased proportion of phospholipid in the cooked turkey system may be related to the fact that poultry meat contains more unsaturated fatty acids (Hilditch et al., 1934; Chang and Watts, 1952) than either beef or pork, and the fact that phospholipids contained a much higher percentage of unsaturated fatty acids than neutral lipids (Hornstein et al., 1961) which might allow a melting out of phospholipids accounting for the decrease or the phospholipid may break down during cooking so they are not measured by the analysis procedure used.

No clear explanation can be given for the very highly significant decrease in the neutral lipid content of the raw and cooked 0% soy substituted turkey systems. Even though the neutral lipid values for the other 0% and 30% soy substituted meat systems were not the same, they did show the same trends, however this was not the case with the turkey system. There are several possible explanations for these results. First, insufficient solvent may have been used to elute the neutral lipid from the silicic acid, however there should have been a substantial increase in the phospholipid content since the solvent used in this step was more polar, but this was not the case. Another possibility is that not enough solvent was used to elute all of the phospholipid from the silicic acid, which would indicate that the phospholipid content is low. The other possible explanation is that the neutral lipid oxidized much more rapidly when the solvent was being evaporated off the the loss occurred in that step.

No studies were found in the literature which compared the types of lipids present in raw and/or cooked soy substituted meat systems. It is interesting to note that in each case the percentage phospholipid appeared to be slightly higher for the 30% soy substituted meat systems than for the 0% soy substituted meat systems, however analysis of variance showed that the difference was not significant. This slight increase may be attributed to the fact that of the 1% residual fat which remains after processing or textured soy protein products, up to 30% of this lipid may be phospholipids (Williams, 1974; Blair, 1974).

TBA Determinations

In order to evaluate the addition of 30% soy on the quality of cooked stored meat systems, 2-thiobarbituric acid tests were used to determine the rate of oxidative rancidity under refrigerated ($5^{o}C$) and frozen ($-11^{o}C$) conditions. The TBA values are reported in Table 10, and the analyses of variance to determine significant differences for the level of soy and storage periods (refrigerated and frozen) are presented in Table 11.

The slow increase in oxidation of ground beef under both refrigerated and frozen storage can be seen in Fig. 1. The only significant difference that occurred between the TBA values of 0% and 30% soy substituted beef was for day 2. There was no significant increase in the rate of oxidation for either the 0% or 30% soy substituted beef stored under refrigerated or frozen storage.

The increase in rancidity for the 0% and 30% soy substituted pork systems can be seen in Fig. 2. There appeared to be a substantial increase, then a leveling off of TBA values for the refrigerated pork loaves. This increase in rancidity was very highly significant ($p<0.01$), however soy substitution did not significantly affect TBA values.

The frozen pork systems became much more rancid (Fig. 2) than did the beef systems frozen for the same period of time. There was,

Table 10. Means and standard deviations of TBA Numbers[a] for soy substituted meat systems stored at 5°C and -11°C.

Temperature	Time	Beef		Pork		Turkey	
		0%	30%	0%	30%	0%	30%
5°C	0 da	2.3±0.4[b]	2.7±0.4	3.3±0.8	3.9±0.8	3.3±0.3	3.9±1.0
	2 da	2.4±1.1	3.3±0.8	5.5±2.4	5.8±2.3	4.4±0.8	4.0±0.9
	4 da	2.2±0.3	2.8±0.5	5.4±1.1	5.3±2.1	5.5±0.5	4.4±0.7
-11°C	1 wk	2.2±0.3	2.8±0.6	6.1±2.4	6.0±1.0	4.3±0.5	4.2±0.8
	2 wk	2.4±0.4	2.6±0.7	6.1±1.0	4.8±2.0	3.9±0.5	3.3±0.5
	3 wk	2.6±0.8	3.0±0.6	7.3±1.8	5.5±2.3	5.4±0.5	5.1±0.8

[a] Reported as mg of malonaldehyde/1000 g of sample, based on the distillation constant (k=14.9) as determined by Witte *et al*., 1970.

[b] Based on 5 replications.

Table 11. Analyses of variance for TBA Numbers for storage period and percentage of soy in soy sbustituted meat systems.

Temperature	Source	df	Mean Square		
			Beef	Pork	Turkey
	Total	29			
	Soy	1	2.640**	1.323	1.240
$5^{o}C$	Storage	2	0.469	9.787***	6.146***
	Interaction	2	0.184	0.619	2.666*
	Within	24	0.217	2.714	0.550
	Total	39			
	Soy	1	1.600*	8.556	67.340
$-11^{o}C$	Storage	3	0.208	10.880	67.552
	Interaction	3	0.057	4.322	101.511
	Within	32	0.243	2.716	63.127

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.
***Significant at the 0.1% level of probability.

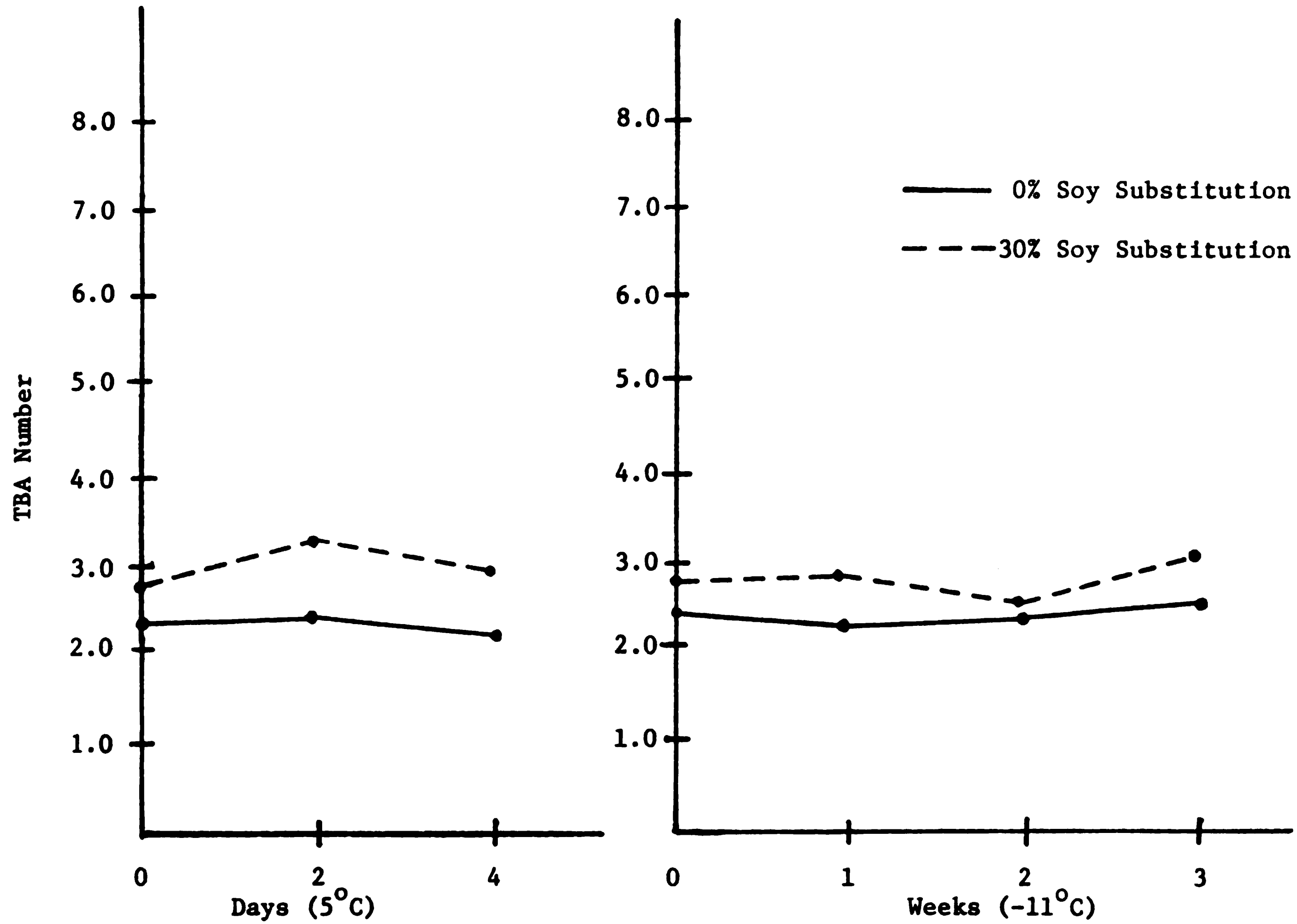

Fig. 1. TBA Numbers for 0% and 30% soy substituted ground beef stored at 5°C and -11°C.

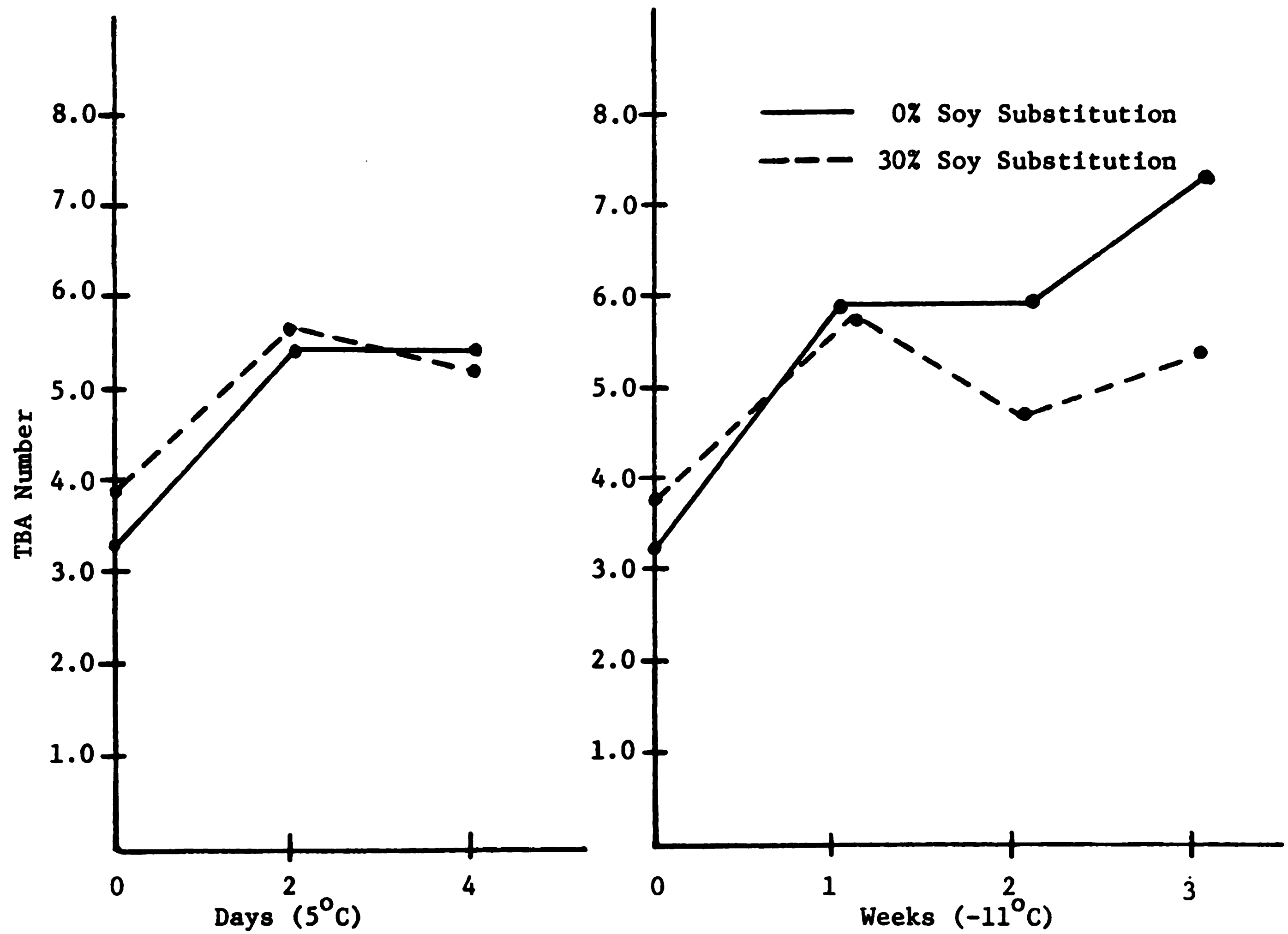

Fig. 2. TBA Numbers for 0% and 30% soy substituted ground pork stored at 5°C and -11°C.

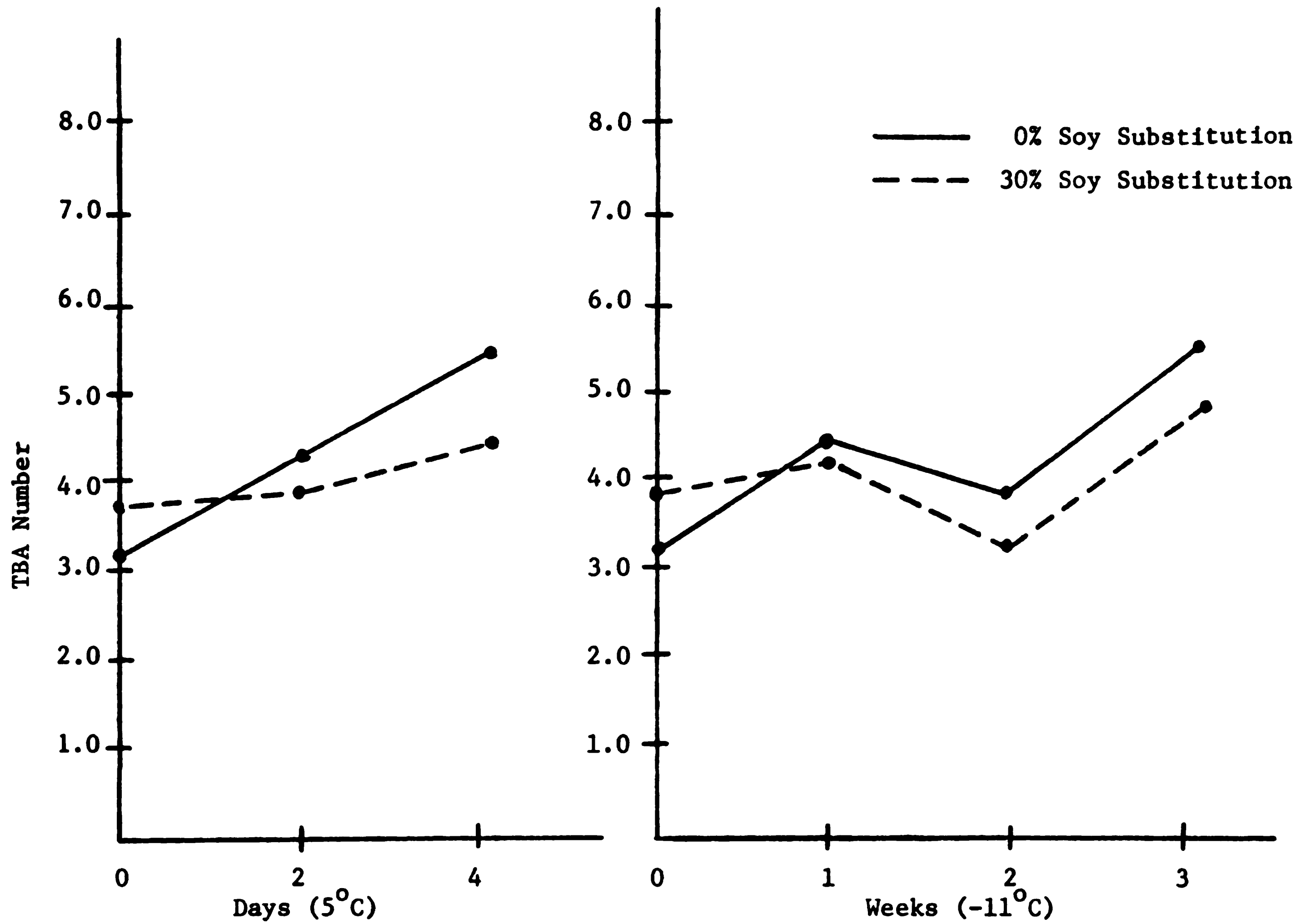

Fig. 3. TBA Numbers for 0% and 30% soy substituted ground turkey stored at 5°C and -11°C.

however, no significant increase in rancidity found in the three week frozen storage of the pork systems stored for 3 weeks.

The increase in oxidation for the frozen and refrigerated turkey systems is illustrated in Fig. 3. The 0% soy soubstituted turkey shows a steady increase in TBA values during the refrigerated storage, whereas the 30% soy substituted turkey shows a much slower rate of increase. This steady increase for the 0% soy substituted turkey was found to be very highly significant (Table 11). There was a significant ($p<0.05$) difference in TBA values between the 0% and 30% soy substituted turkey for day 4, with the 30% soy substituted turkey being much less rancid. There was no significant increase in rancidity either in the 0% or 30% soy substituted frozen turkey, nor was there a significant difference between the 0% and 30% soy substituted turkey loaves for any given week.

The 2-thiobarbituric acid test measures the amount of malonaldehyde that has been produced as a result of autoxidation. The oxidation of cooked meat is believed to be catalyzed by ferric heme derivatives formed during thermal heating (Younathan and Watts, 1959, 1960). Fox (1966) reported that as a result of cooking the pigments in uncured meats are irreversible converted to the denatured ferric chromogen. Therefore uncured meats would be expected to increase lipid oxidation, which is responsible for the stale, off-odors associated with reheated cooked meats (Toms and Watts, 1958).

Cooked beef stored in the refrigerator would be expected to increase more rapidly than if stored in the freezer (Chang _et al._, 1961). The results from this study indicate that rancidity did not increase significantly in either the 0% or 30% soy substituted beef after 4 days at 5°C. The beef systems oxidized much slower at -11°C than at 5°C as was expected. The soy did not have a significant effect on the level of rancidity in the -11°C stored beef, and the only significant difference was noted for day 2 for the beef systems stored at 5°C.

Cured meats can be held longer at refrigerated temperatures than at a freezer temperature (Younathan, 1959). The stability of the refrigerated cured meats towards lipid oxidation is also high compared to the stability of uncured meats held under the same condition (Zipser et al., 1964). The reason cured meats are more stable toward lipid oxidation at refrigerated conditions is that the sodium nitrite used in curing converts the pigments to the catalytically inactive ferrous nitric oxide (Younathan and Watts, 1959). Pigment losses have been shown to parallel lipid oxidation in refrigerated hams, with the cured meat pigment being oxidized to the ferric form or the prophyrin ring is destroyed (Younathan and Watts, 1959). The pork system in this study consisted of a 50:50 mixture of cured ham and uncured ground pork. The pork system would therefore not be expected to be as stable towards lipid oxidation as if only cured ham had been used. There was a greater increase in rancidity in the pork systems under 5°C than with the beef systems stored under the same condition. Pork lipids are more highly unsaturated than beef lipids and would be more easily oxidized (Watts, 1954).

Lipid oxidation that occurs in frozen cured pork is salt catalyzed rather than heme catalyzed as in the other two systems. The proposed mechanism for this was reported earlier. There was a much more rapid increase in lipid oxidation with the pork systems stored at -11°C than with either the beef or turkey systems stored under the same conditions. There were no significant differences between the 0% and 30% soy substituted pork loaves stored under refrigerated conditions. There was also no significant increase in rancidity for either of the two frozen pork systems as would have been expected. This lack of rancidity development might be due to the fact that the individual replications of the pork system more than those of the other meat systems varied so (Table 10) which caused higher standard deviations than were found for the other systems.

Poultry lipids are much more highly unsaturated than beef pork lipids (Hilditch et al., 1934; Chang and Watts, 1952) and would be expected to show a marked increase in lipid oxidation under refrigerated storage, as was shown by the results in this study (Fig. 3). Jacobson and Koehler (1970) reported a decrease in flavor evaluation for refrigerated dark turkey meat during a 4-day storage; with corresponding increase in TBA values. They recommended freezing cooked turkey immediately after cooking in order to delay the development of off-odors and flavors associated with lipid oxidation. Marion and Forsythe (1971) attributed the increased lipid oxidation in dark poultry meat to the fact that heme catalysis is more active in red muscle, which contains a larger amount of myoglobin than does white muscle from poultry. The increase in rancidity for the turkey systems stored at -11°C was much slower as was expected. Soy substitution did not significantly affect the TBA values in the turkey systems stored at -11°C.

The 30% soy substitution significantly ($p<0.001$) reduced the rate of lipid oxidation in turkey systems stored at 5°C. Soy substitution had also reduced the rate of lipid oxidation in the beef systems at $5^{o}C$ ($p<0.05$) but this reduction occurred only for the values for day 2 of storage.

Carlin and Nielson (1974) reported that after 6 months storage at $-4^{o}F$ randicity was not as detectable in a 30% soy substituted beef loaf as it was in the 0% soy substituted beef. They attributed this to either an antioxidant property of the soy or that the strong flavor masked the off-flavor associated with lipid oxidation.

The antioxidant affect of soy has been reported in the literature as being related to the naturally occurring flavanoid compounds (Pratt, 1970), or to substances produced as a result of interactions between amino acids or proteins and carbohydrates upon heating (Sato et al., 1973). The flavanoid compounds are water soluble and unless bound in some way, would be lost during the processing of a textured soy protein. However, there are no reliable quantitative methods for determining the flavone compounds in the textured or spun fiber products (Blair, 1974).

Sato et al., (1973) reported a lower TBA increase with a 2% soy substituted ground meatloaf stored at $4^{o}C$ for 2 and 5 days than with the 0% soy substituted ground meat systems, stored under the same conditions. They attributed this stability towards the development of rancidity to the production of reducing-type compounds as inhibitors of WOF. Vegetable protein products contain appreciable amounts of carbohydrate and protein (Rakosky, 1971). The Temptein used in this study contained 64.0% protein and 18.4% carbohydrate. These reducing-type substances would occur as a result at interaction between amino acids and proteins of meat and soy and the carbohydrates of soy and meat, upon heating.

SUMMARY AND CONCLUSIONS

This research project investigated the affects of a 30% soy substitution on ground beef, pork and turkey systems. Cooking losses, sensory characteristics of flavor, juiciness, mouthfeel and overall acceptability and TBA values, which determines the rate of oxidative rancidity, were evaluated for cooked loaves prepared with 0% and 30% soy substitutions. Both the raw and cooked 0% and 30% soy substituted meat systems were also analyzed for moisture, total lipid, phospholipid and neutral lipids.

The taste panelists scored the 30% soy substituted beef and turkey systems slightly lower than the non-soy substituted system, but all scores were above 4.6 on a 7 point scale and none of the differences were significant. However, taste panelists scored the 30% soy substituted pork system significantly lower than the 0% soy substituted pork system for all quality characteristics except mouthfeel. Since the textured soy protein used in this study was engineered to blend with beef, it was expected to blend well with the turkey system, however color differences were obvious between the 0% and 30% soy substituted ham loaf which would contribute to the lower scores.

The 30% soy substitution decreased total cooking losses in both the beef and pork systems. Soy substitution decreased drip loss in all three systems; nevertheless, no differences were found in volatile losses between the 0% and 30% soy substitutions in any of the three systems.

Cooking resulted in very highly significant decrease in percentage moisture for the 0% soy substituted beef and turkey systems, for all three 30% soy substituted systems.

Due to dilution with a low fat product the raw 30% soy substituted beef, turkey and pork systems had significantly less fat than did corresponding 0% soy substituted meat systems. The 30% soy substituted systems, however, retained more total lipid than did the 0% soy substituted systems, therefore there was no significant difference between the total lipid content of the cooked 0% and 30% soy substituted beef and pork systems. Thus, consuming 30% soy substituted meat would not be a beneficial way to decrease the total number of calories or the amount of fat in one's diet.

The amount of phospholipid in both the 0% and 30% soy substituted beef and pork systems increased as expected. The decrease in phospholipid content of the 0% and 30% soy substituted turkey systems might be explained by the fact that poultry is much more highly unsaturated and contains a larger percentage of phospholipid than the other two systems. There appeared to be no significant difference in neutral lipid content as a result of cooking for either the 0% or 30% soy substituted beef or pork systems, while the only significant difference was found between the 0% and 30% soy substituted turkey systems, with the 0% soy substituted system containing less neutral lipid.

The TBA values indicated that the 30% soy substituted systems were initially slightly more rancid, but at some point during either refrigerated or freezer storage, the rate of oxidation for the 0% soy substituted pork and turkey increased more rapidly so that their TBA values were higher than those of the 30% soy substituted meat systems after storage. The only significant difference in TBA values of 0% and 30% soy substituted meat, however occurred in the refrigerated turkey system. The ground beef underwent oxidative rancidity at a much slower rate during storage at both refrigerated and freezing temperatures, than did the other two types of meat systems, and the 30% soy substituted beef system had higher TBA values throughout the storage periods.

The data from this study seem to indicate that:

1. Use of 30% soy substitution did not adversly affect the quality characteristics of ground beef and turkey systems.
2. Ham loaves substituted with 30% soy were judged to be less flavorful, have less desirable color and lower overall acceptability.
3. No differences were found in the total lipid content of the 0% and 30% soy substituted meat systems.
4. Fat contents were similar in the beef and pork soy substituted meat systems.
5. Although 30% soy substituted meat systems appeared to have a slightly lower TBA value during refrigerated and frozen storage, soy does not appear to prevent the development of WOF in cooked meats.

PROPOSALS FOR FUTURE RESEARCH

A number of interesting observations were made during this study which warrant further investigation. The following areas of research are proposed:

1. The trend of a slower rate of oxidation with the 30% soy substituted meat systems should be investigated more thoroughly. Model systems using unsaturated fatty acids and soy protein extracts would indicate more specifically whether or not the soy protein exhibited antioxidant properties.

2. Further study is needed to determine whether or not soy protein products interfere wieh the TBA determinations by forming complexes with the malonaldehyde, which in turn would give lower values.

3. The turkey phospholipid and in particular the neutral lipid results of this study and the lack of published results indicates that additional studies should be conducted to determine what changes occur in poultry lipids as a result of cooking.

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APPENDICES

APPENDIX I

ANALYSES OF VARIANCE FOR PRELIMINARY EVALUATION OF VARIOUS SENSORY CHARACTERISTICS

OF 0%, 15% and 30% SOY SUBSTITUTED MEAT SYSTEMS

Source	df	Mean Squares						
		Exterior Appearance	Interior Appearance	Interior Color	Flavor	Juiciness	Mouthfeel	Overall
Total	14							
Soy	2	0.168	0.459	0.131	9.843**	1.422*	0.289	5.011**
Replication	4	1.396	0.283	0.147	0.54	0.306	0.971	0.289
Within	8	0.798	0.319	0.171	0.256	0.262	0.287	0.137

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

APPENDIX II

SCORECARD FOR GROUND MEAT SYSTEMS

Sample________________ Name____________________

Date___________________

Directions:

1. Put name and date on score card.

2. Read the scorecard over carefully.

3. Each sample has a number. Record its data by making an X through the box on the corresponding numbered scorecard.

4. If there is an "off" flavor please describe.

Score	Flavor	Juiciness	Mouthfeel	Overall
1	very bland	very dry	mushy	
2				
3	mod. bland	mod. dry	mod. mushy	
4				
5	sl. bland	sl. dry	sl. mushy	
6				
7	meaty and pleasantly spiced	juicy	pebbly	excellent
6				
5	sl. off	sl. wet	sl. gritty	good
4				
3	mod. off	mod. wet	mod. gritty	poor
2				
1	off	very wet	gritty	unaccept-able

Comments: