Technology for the Development

of a Microwavable Pork Chop

by

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ABSTRACT

Whole muscle cuts and restructured chops were conventionally cooked, microwave cooked, and precooked/ microwave reheated. Whole muscle samples had an additional treatment of blade tenderization. All samples were stored for three storage periods of 2, 15, and 21 days. Precooked samples were evaluated for appearance traits. Blade tenderization did not affect ($P>0.05$) the traits evaluated with the exception of texture. Precooked products had higher ($P<0.05$) TBA values than conventionally cooked samples of both whole and restructured chops. Conventionally cooked chops had the lowest ($P<0.05$) TBA value in both whole muscle and restructured cuts, the lowest ($P<0.05$) peak force value and the highest ($P<0.05$) sensory scores in whole muscle samples. TBA values increased ($P<0.05$) with storage time for up to 21 days. Over 21 days of storage of whole muscle samples, Warner-Bratzler peak force values and overall flavor scores decreased ($P<0.05$) and juiciness and texture scores improved ($P<0.05$). Storage did not affect ($P>0.05$) peak force values and sensory scores of restructured samples.

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CHAPTER I

INTRODUCTION

The number of dollars spent by consumers in grocery stores for pork has increased 29% from 1978 to 1988 (AMI, 1990). This can be accounted for by the change in the physiology of swine. Since the 1950's, pigs have been bred to be more muscular which has resulted in 50% leaner pork (Anon., 1986). Consumers are looking for nutritious and convenient foods (Schmidt et al., 1986) and seven out of ten people view pork as nutritious (Anon., 1986).

Pork is an uncommon item on most restaurant menus. However, a recent survey revealed that 60% of people surveyed would order pork if it were available on the menu (Anon., 1986). As pork gains more acceptance, consumption should continue to rise since 42.7% of average food expenditures is spent on meals eaten away from home (Exter, 1990).

Restructuring technology may result in pork achieving greater acceptance on restaurant menus as well as in institutions such as college cafeterias and hospitals. This technology offers products that are uniform in shape and portion size (Mandigo, 1974; Quenzer et al., 1982; Mandigo, 1986; Schmidt et al., 1986). These are the traits that institutions and restaurants seek (Mandigo, 1974; Quenzer et al., 1982; Mandigo, 1986).

Precooked pork products may also have an impact on pork consumption. Over the years there has been an increase in the demand for foods that are quick and easy to prepare (Jones et al., 1987). Precooking has the potential to offer a quick, easy (Penner and Bowers, 1973; Jones et al., 1987) and economical (Boles and Parrish, 1990) way to prepare pork in the home, at restaurants and institutions. Precooked meats require less time for preparation with less cooking loss (Emswiler et al., 1979). Precooked meats are convenient (Johnston and Baldwin, 1980) because of ease in preparation (Nolan et al., 1989) which is valued in today's fast paced lifestyle.

Microwave cooking also adds convenience in meal preparation (Paterson and Parrish, 1988; Mudgett, 1989) which has led to more than 70% of U.S. households with microwave ovens (Mudgett, 1989). Whorton and Reineccius (1990) predicted that this level would increase to greater than 90% by 1990. This increase can be attributed to enhanced convenience, time and energy savings, low cost, and improvements in the overall design of the microwave oven (Mudgett, 1989; Rourke et al., 1992). However, most consumers use the microwave oven for reheating and defrosting (Anon., 1985). Foodservice establishments also incorporate about 80% of the use time of the microwave oven for reheating (Hoffman and Zabik, 1985). With this in mind, microwave ovens are ideal for reheating precooked products in foodservice establishments, restaurants, institutions, and homes.

There are, however, limitations to microwave cooking, precooking, and restructuring. With traditional microwave cookery, the surface of meat is not browned and overcooking of edges and corners of products may occur (Mudgett, 1989). Precooking meat products results in the development of warmed-over flavor (Penner and Bowers, 1973) which is undesirable. Restructured products have not been widely accepted (Seideman and Durland, 1983) because of the discoloration of the product (Chu et al., 1987; Trout, 1989a; Trout, 1989b) and the development of lipid oxidation during storage (Ockerman and Organisciak, 1979; Marriott et al., 1987).

The objectives of this research were to compare various methods of cooking (conventional, microwave, and precooked) whole muscle pork loin chops and restructured pork chops after different storage periods (2, 15, and 21 days).

CHAPTER II

REVIEW OF LITERATURE

2.1 PALATABILITY ENHANCEMENT

2.11 Blade Tenderization

Blade tenderization is a method of mechanical tenderization that is widely used by the meat industry to improve product acceptability (Hayward et al., 1980; Loucks et al., 1984; Wheeler et al., 1990). It is the mechanical destruction of connective tissue and muscle fibers (Judge et al., 1989). There are numerous studies which demonstrate the affects of blade tenderization of beef on surface discoloration, overall appearance, flavor, juiciness, and tenderness as determined by Warner-Bratzler shear and sensory panel evaluation. The consensus of this research is that blade tenderization improves tenderness without adverse affects on other characteristics.

Generally, Warner-Bratzler shear values of beef decreased due to one pass through a mechanical tenderizer (Glover et al., 1977; Savell et al., 1977; Seideman et al., 1977; Smith et al., 1979; Hayward et al., 1980; Savell et al., 1982; Loucks et al., 1984; Bidner et al., 1985; Seideman et al., 1986; Medeiros et al., 1989). Wheeler et al. (1990) found that Warner-Bratzler shear values were lower for blade tenderized samples, but this difference was not significant. However, Tatum et al. (1978) found no differences in Warner-Bratzler shear values between blade tenderized and non-blade tenderized beef from mature cows and bulls.

Sensory panel tenderness scores of beef were also improved with blade tenderization (Davis et al., 1977; Glover et al., 1977; Savell et al., 1977; Smith et al., 1979; Hayward et al., 1980; Savell et al., 1982; Bidner et al., 1985; Seideman et al., 1986; Medeiros et al., 1989; Wheeler et al., 1990). One study by Tatum et al. (1978), however, found no significant difference in sensory panel tenderness scores of beef with up to two passes through the blade tenderizer. The beef in this study, however, was from mature bulls and cows.

Blade tenderization of beef decreased sensory panel juiciness scores in several studies. Glover et al. (1977) found that sensory panel juiciness scores of beef roasts showed blade tenderized samples as being less juicy. Blade tenderized beef strip loins had lower sensory panel juiciness scores than non-blade tenderized loins (Savell et al., 1977). Savell et al. (1982), Bidner et al. (1985), and Wheeler et al. (1990) also found that blade tenderization of beef resulted in lower sensory panel juiciness scores. However, other researchers have found that blade tenderization had no effect on sensory panel juiciness scores of beef strip loins (Davis et al., 1977), beef roasts (Loucks et al., 1984), and beef steaks (Glover et al., 1977; Tatum et al., 1978; Smith et al., 1979; Hayward et al., 1980; Seideman et al., 1986; Medeiros et al., 1989).

Sensory flavor attributes of beef does not appear to be affected by blade tenderization. There were no differences noted in blade tenderized beef steaks and beef roasts compared to non-blade tenderized samples in a study conducted by Glover et al. (1977). Davis et al. (1977) found no change in sensory panel flavor scores with tenderized beef strip loins. No differences in flavor attributes between blade tenderized and non-blade tenderized beef were found by Tatum et al. (1978), Hayward et al. (1980), Savell et al. (1982), Seideman et al. (1986), Medeiros et al. (1989), and Wheeler et al. (1990). However, Seideman et al. (1977) and Smith et al. (1979) found that flavor desirability of blade tenderized beef was higher than non-blade tenderized samples. Flavor intensity of blade tenderized beef was lower than non-blade tenderized samples in a study conducted by Bidner et al. (1985).

Davis et al. (1977) explored the effects of blade tenderization of beef on visual appearance. They found that surface discoloration was not affected by blade tenderization, but the overall appearance was less desirable.

2.12 Restructuring

Today's lifestyle is causing a demand for smaller portion sizes (Mandigo, 1986; Shackleford et al., 1989), fast food, convenience items, and an increase in the number of meals eaten outside the home (Mandigo, 1986). Institutions such as college cafeterias, hospitals, restaurants, and fast food chains are interested in products that are uniform in shape and portion size (Mandigo, 1974; Quenzer et al., 1982; Mandigo, 1986). Restructuring technology can be used to achieve uniformly shaped and sized products (Mandigo, 1974; Quenzer et al., 1982; Mandigo, 1986; Schmidt et al., 1986). However, these products have not been widely accepted among consumers or the institutional market (Seideman and Durland, 1983) for several reasons. Limitations of restructured meats include discoloration of the product during storage (Chu et al., 1987; Trout, 1989a; Trout, 1989b) and the development of lipid oxidation during storage (Ockerman and Organsiciak, 1979; Marriott et al., 1987).

Restructuring technology increases the value of less desirable cuts of meat by reforming the product (Wiebe and Schmidt, 1982; Seideman and Durland, 1983; Flores et al., 1986; Lamkey et al., 1986; Mandigo, 1986) into roasts, steaks, chops, cutlets, strips, or cubes (Mandigo, 1986). Lean and fat components make up the raw materials (Mandigo, 1986) which determine the composition and texture of the finished product

(Schmidt et al., 1986). The fat component contributes to juiciness and flavor (Mandigo, 1986). Often, tenderization of the lean component is used to break up collagen (Mandigo, 1986). The particle size of the component parts is reduced by grinding (Mandigo, 1986), flake-cutting, slicing (Seideman and Durland, 1983; Mandigo, 1986), or sectioning (Seideman and Durland, 1983). Depending on the desired product, non-meat ingredients such as salt, phosphates, water, seasonings, and natural spices may be added during mixing (Seideman and Durland, 1983; Mandigo, 1986). Mixing serves several functions. It homogenizes the mixture (Mandigo, 1986), incorporates the non-meat ingredients, and extracts muscle proteins that increase binding between meat particles (Seideman and Durland, 1983; Mandigo, 1986). Mixing also allows colder meats or cryogenic compounds to be added which reduce the temperature to achieve adequate forming of the meat mass (Mandigo, 1986). Mandigo (1986) suggested that texture can be affected by mixing time. Over mixing can cause a loss in steak-like texture, reduce binding of the particles, and increase production time (Mandigo, 1986). Texture is also affected by the type of mixer, tumbler or massager, mixing speed, whether or not a vacuum is used in the mixer, and the ratio of product to the capacity of the mixer (Mandigo, 1986).

After mixing, the product is formed into the desired shape, size, and weight (Mandigo, 1986; Schmidt et al., 1986).

According to Mandigo (1986), there are three common approaches used to form restructured products. The most widely used is the stuff-freeze-temper-slice concept which can be time consuming and cause color degradation during frozen storage (Mandigo, 1986). For a pattie-like product, the slide plate forming machine is used in which temperature is an important factor (Mandigo, 1986). The third method is a cavity-fill machine which offers the advantage of continuous flow (Mandigo, 1986). Once forming is complete, the product can be battered, breaded, or cooked (Mandigo, 1986). To maintain a consistent shape, most products are sold frozen or partially frozen (Seideman and Durland, 1983). Mandigo (1986) suggests that the best texture and flavor are obtained by using the most rapid freezing technique possible.

2.13 Role of Cookery

Increased cooking temperature to 80° C causes many changes in muscle. These alterations occur in moisture content (Simmons et al., 1985; Fjelkner-Modig, 1986; Heymann et al., 1990), tenderness (Glover, 1977; Simmons et al., 1985; Fjelkner-Modig, 1986), pork flavor (Simmons et al., 1985; Heymann et al., 1990), and color and lipid content (Heymann et al., 1990). A decrease in moisture content results in less juicy pork (Simmons et al., 1985; Fjelkner-Modig, 1986; Heymann et al., 1990). In pork, sensory panel tenderness scores decrease and Warner-Bratzler shear values increase with additional heating indicating a less tender product (Simmons et al., 1985). Fjelkner-Modig (1986) observed that sensory panel tenderness scores decreased with additional heating to 80° C. Glover et al. (1977) found decreased tenderness in beef as determined by Warner-Bratzler shear values with an increase in temperature from 70° C to 80° C. However, Heymann et al. (1990) found that tenderness in pork was not influenced by increased temperatures (65.6, 71.7, 76.7, 82.2° C). Simmons et al. (1985) and Heymann et al. (1990) observed an increase in pork flavor with increased temperature. This could be attributed to the length of exposure to heat (Simmons et al., 1985). According to Judge et al. (1989), volatile compounds are driven off upon heating. Heymann et al. (1990) also observed a less pink color and an increase in percentage lipid in pork with increased heating. In contrast, Simmons et al. (1985) observed that percentage lipid did not differ significantly with increased temperature.

2.2 LIPID OXIDATION

Lipid oxidation occurs in meats when they are exposed to oxygen present in air (Melton, 1983; Pearson, et al., 1983; Younthan, 1985) and is accelerated by light (Penner and Bowers, 1973; Dugan, 1987), thermal treatment (Sato and

Hegarty, 1971; Penner and Bowers, 1973; Wilson et al., 1976; Younathan, 1985;), and the presence of iron that is not heme bound (Igene et al., 1979; Younathan, 1985). Fresh and processed meat products are susceptible to lipid oxidation (Wilson et al., 1976; Schmidt, 1988) as are precooked meat products (Tims and Watts, 1958; Penner and Bowers, 1973; Wilson et al., 1976; Pearson et al., 1977; Campbell and Mandigo, 1978; Johnston and Baldwin, 1980; Albrecht and Baldwin, 1982; Cordray et al., 1986).

Oxidative rancidity or lipid oxidation occurs when unsaturated fatty acids such as oleic, linoleic, linolenic, and arachidonic, (Younathan, 1985) react with oxygen (Melton, 1983; Pearson et al., 1983; Younthan, 1985). This reaction is called autoxidation which has three steps (initiation, propagation, and termination). During propagation, a hydroperoxide is formed which decomposes to form hexanal, pentanal, and malonaldehyde which contribute to off-flavors (Pearson et al., 1983).

2.21 Rancidity, Warmed-over Flavor, and TBA Values

Oxidative rancidity is the development of undesirable flavors and odors due to the reaction of oxygen with fat (Freeland-Graves and Peckham, 1987; McWilliams, 1989). The undesirable flavors associated with rancidity in precooked products are described as warmed-over flavor (Tims and Watts, 1958; Sato and Hegarty, 1971). Warmed-over flavor occurs because of the autoxidation of unsaturated fatty acids. Phospholipids contribute to warmed-over flavor (Hornstein and Wasserman, 1987).

The 2-thiobarbituric acid test, or TBA test, is most commonly used to measure lipid oxidation (Tarladgis et al., 1962; Gray, 1978). With this test, a higher TBA number indicates more oxidation or rancidity (Tarladgis et al., 1960; Tarladgis et al., 1964; Ockerman and Organisciak, 1979). Tarladgis et al. (1960) concluded that the detection of off-odor in pork had a threshold range of TBA values of approximately 0.5 to 1.0, while Tims and Watts (1958) observed that sensory panel judges were able to detect off-flavors in pork at TBA values above 0.5.

2.22 Effects of Storage

Storage time had no effect on the TBA values of raw pork chops in refrigerated storage packaged in oxygen impermeable bags or overwrapped with PVC film for up to 21 days (Igbinedion et al., 1983). The results of the oxygen impermeable bags was attributed to the lack of oxygen. The results of the PVC film were not expected and were accounted for by possible microbial interference (Igbinedion et al., 1983).

Paterson and Parrish (1988) observed a significant increase in TBA values in vacuum packaged precooked beef roasts in refrigerated storage. The TBA values reached a peak at day 14. After day 14, they decreased and were not significantly different for the remainder of the storage period. Albrecht and Baldwin (1982) found that lipid oxidation in precooked pork roasts occurred as a result of refrigerated storage. In agreement are Hsieh and Baldwin (1984) who found that lipid oxidation in precooked beef roasts occurred during refrigerated storage and concluded that increased holding time resulted in higher TBA values indicating additional oxidative rancidity. Chang et al. (1961) found a rapid accumulation of oxidized products in precooked beef in refrigerated storage. The TBA values of refrigerated samples increased from day one through day 18 of storage (Chang et al., 1961). Miller et al. (1985) found that TBA values for precooked pork chops wrapped in laminated freezer paper increased after 28 days of frozen storage. Uncooked beef top rounds wrapped in laminated freezer paper in frozen storage showed no significant change in TBA values over a nine month period (Law et al., 1967). However, the TBA values of raw beef loin steaks wrapped in laminated freezer paper increased significantly between six months and nine months of frozen storage in the same study.

In a study conducted by Ockerman and Organisciak (1979), TBA values of vacuum packaged raw restructured beef steaks in refrigerated storage increased with storage time. Marriott et al. (1987) observed higher TBA values with increased storage up to 56 days in raw restructured pork wrapped in wax coated freezer paper and stored at -20° C. An increase in TBA values between the storage times of zero and two weeks in vacuum packaged precooked restructured pork patties in frozen storage was reported by Campbell and Mandigo (1978). The TBA values remained high for the remaining six weeks of storage.

Refrigerated storage for raw ground meat does not consistently cause an increase in TBA values (Tims and Watts, 1958; Younathan and Watts, 1960). Tims and Watts (1958) observed only slight changes in TBA values in raw ground meat samples after a refrigerated storage period of one to two weeks (packaging material unknown). Bidlack et al. (1972) found that the TBA values of raw ground pork samples stored at 3° C in sealed No. 2 cans for up to 26 days did not increase. Witte et al. (1970) observed increases in TBA values of raw pork cubes and raw ground beef packaged in polyethylene bags in refrigerated storage over a period of seven days. The changes in TBA values after three days of storage were significant (Witte et al., 1970). Increased storage time (0, 28, and 56 days) at -1° C and 4° C of raw ground pork caused an increase in TBA values in a study reported by Bentley et al. (1987). Witte et al. (1970) observed no significant changes in TBA values of raw ground beef packaged in polyethylene bags in frozen storage over seven days. There were no significant increases in TBA values of raw pork cubes packaged in polyethylene bags in frozen storage (-20° C) for two to seven days in a study done by Witte et al. (1970).

Younathan and Watts (1960) observed that precooked ground pork (packaging material unknown) reached a near maximum TBA value in four days of refrigerated storage and remained high for the remainder of the ten day storage period. Willemot et al. (1985) evaluated precooked ground pork stored in glass petri dishes in refrigerated storage for up to 16 days and determined that TBA values increased sharply from day zero to day eight and remained high for the remaining storage time. Precooked ground pork in refrigerated storage evaluated through sensory and chemical tests will undergo oxidative changes within 18 hours of storage (Nolan et al., 1989). Keller and Kinsella (1973) found that TBA values of precooked ground beef wrapped in commercial freezer paper increased with frozen storage.

2.23 Relationship of TBA Values to Sensory Traits

Lipid oxidation is a major factor involved in the deterioration of meat (Gray, 1978; Melton, 1983; Pearson et al., 1983; Younathan, 1985; Schmidt, 1988). This can lead to the development of undesirable rancid odors and flavors

(Greene and Cumuze, 1981; Younathan, 1985; Dugan, 1987; Schmidt, 1988; Judge et al., 1989) that have been termed as warmed-over flavor or warmed-over aroma in precooked products (Tims and Watts, 1958; Sato and Hegarty, 1971).

Many studies have been done to relate the objective TBA value to a subjective sensory score. One of the first investigators was Tarladgis et al. (1960) who found a highly significant correlation (0.89) between TBA values and rancid odor. Zipser et al. (1964) reported a very high correlation (0.92) between rancid odor and TBA numbers in cured and uncured frozen cooked pork. Albrecht and Baldwin (1982) found that panelists appear to perceive lipid oxidation in precooked roast pork as warmed-over flavor and warmed-over aroma. They also observed a significant positive correlation between TBA values and intense warmed-over aroma and warmed-over flavor. Hsieh and Baldwin (1984) also found that warmed-over flavor and warmed-over aroma were highly correlated in precooked roast beef. Both of these were correlated with TBA values. They concluded that more intense warmed-over flavor and warmed-over aroma was associated with increased TBA values. Penner and Bowers (1973) observed significant correlations between TBA values and stale aroma and astringent flavor in microwave reheated pork. There was also a significant correlation between TBA numbers and warmed-over flavor scores in beef, chicken white meat (Igene and Pearson, 1979; Igene et al., 1979), and dark meat of chicken (Igene and Pearson, 1979). MacDonald et al. (1980) concluded that TBA values could be used to predict off-flavor and off-odor formation in cured meat.

According to Miller et al. (1985), TBA values are significantly related to flavor score changes in precooked, cured pork chops. Willemot et al. (1985) observed increased warmed-over aroma scores in pork in an eight day period and an increase in TBA values in that same time indicating a high correlation between TBA values and sensory panel evaluation. The results of a study done by Poste et al. (1986) using pork showed a significant relationship between TBA values and the formation of off-odor and off-flavor. Nolan et al. (1989) found that TBA values correlated well with warmed-over flavor scores in turkey and pork. Brewer et al. (1992) concluded that rancid odor scores in raw ground pork correlated with TBA values. Hwang et al. (1990) also reported high correlation coefficients between TBA values and sensory scores in frozen cooked beef. There are numerous other relationships between TBA values and warmed-over flavor in cooked meats (Sato et al., 1973), warmed-over flavor in roast beef (Johnston and Baldwin, 1980), flavor palatability determined by sensory panelists in microwave reheated pork roasts (Boles and Parrish, 1990), flavor scores of restructured beef steaks in refrigerated storage (Ockerman and Organisciak, 1979), and rancidity in beef as measured by the sensory panel (Gokalp et al., 1983).

However, there are contrasting research results on TBA measurements. Gray (1978) determined that a relationship between flavor changes and TBA value would need to be established for a given oil before the TBA value could be used as an index of flavor. Igene and Pearson (1979) found that warmed-over flavor scores were not correlated to TBA values in samples of beef, chicken dark meat and white meat. Greene and Cumuze (1981) found low correlation coefficients for TBA values and sensory scores in cooked beef.

Melton (1983) reviewed various methods for determining the amount of lipid oxidation in muscle foods. These methods included peroxide values, 2-thiobarbituric acid test (TBA test), aldehyde measurement by gas chromatography (GC), oxygen absorption, pentane measurement, and fluorescent products. She concluded that peroxide values might not be useful measurements for lipid oxidation in muscle foods stored for prolonged periods and in particularly, ground muscle. Similarly, Gray (1978) stated that peroxide values had limited use only in the initial stages of lipid oxidation. Colorimetric determination of carbonyl compounds is not an accurate method to determine oxidation because inconsistent results have been found with this method (Melton, 1983). This could be due to the decomposition of precursors which creates a problem with the quantification of volatile products (Gray, 1978). Melton (1983) noted that aldehyde measurement by GC appeared to be a good method for measuring lipid oxidation in muscle foods during cooking and throughout storage.

Gray (1978) stated that gas chromatography is best suited for determining lipid oxidation in substances that are pure. He suggested that problems with identification and standardization will arise when complex food systems are used. Oxygen absorption has been successful in the measurement of lipid oxidation in freeze-dried foods (Melton, 1983). Pentane measurements have also been used to measure lipid oxidation in freeze-dried muscle foods (Melton, 1983). According to Melton (1983), there is a limited amount of research illustrating the relationship between fluorescent products and lipid oxidation. However, Gray (1978) indicated that even though more research is needed, fluorescence is a very effective method for determining oxidation. Melton (1983) stated that the TBA test is most likely the best technique to measure lipid oxidation. It has been widely used and accepted by researchers. There are also many modifications for this procedures which make it adaptable to various products (Gray, 1978; Melton, 1983).

2.3 PRECOOKING OF MEATS

The precooking of pork chops that are microwave reheated has the potential to offer consumers a quick, convenient (Penner and Bowers, 1973; Jones et al., 1987), and economical (Boles and Parrish, 1990) way to prepare meat. Precooked meat can be similar in color and visual texture (Campbell and Mandigo, 1978), tenderness (Campbell and Mandigo, 1978; Miller et al., 1985; Jones et al., 1987), juiciness (Miller et al., 1985; Jones et al., 1987), and flavor characteristics of freshly cooked (Jones et al., 1987) and precooked conventionally reheated products (Penner and Bowers, 1973; Albrecht and Baldwin, 1982). In addition to pork, beef roasts are not significantly affected by method of reheating either by microwave oven or conventional oven (Hsieh and Baldwin, 1984).

2.31 Conventional Cookery

Conduction is a method of dry heat which is the physical transfer of heat directly from one molecule to the next (Freeland-Graves and Peckham, 1987; McWilliams, 1989). The transfer of heat through hot air (dry) or water (moist) currents is referred to as convection (Freeland-Graves and Peckham, 1987; McWilliams, 1989). In conventional cookery, food is heated by both conduction and convection currents (Freeland-Graves and Peckham, 1987). The product surface is cooked and browned by dry convection currents and the interior is cooked by moist heat (Freeland-Graves and Peckham, 1987).

Moist heat is generally used to cook less tender cuts of meat because it tends to soften the collagen (Feeland-Graves and Peckham, 1987) with prolonged heat time (McWilliams, 1989).

2.32 Microwave Cookery

Microwave cookery is a dry heat method of food preparation (McWilliams, 1989). In this type of cookery, low frequency electrical energy is converted into electromagnetic radiation by a magnetron which is a device that generates microwaves (Mudgett, 1989). Microwaves penetrate food instantaneously (Mudgett, 1989) and migrate deeper into food than infrared radiation, and therefore, heat the product faster (Bakanowski and Zoller, 1984). Microwaves enter the food and interact with positive and negative charges of water molecules (McWilliams, 1989; Mudgett, 1989), as well as with other food molecules such as sugar and fat (McWilliams, 1989). As the microwaves penetrate the product, hydrogen bonds are disrupted (Mudgett, 1989). As the molecules begin to vibrate (Bakanowski and Zoller, 1984; McWilliams, 1989; Mudgett, 1989), heat is generated by the thermal motion of the oscillating molecules (Bakanowski and Zoller, 1984; McWilliams, 1989; Mudgett, 1989). Deeper penetration by microwaves is observed in products with a high content of solids and low moisture or salt content and results in a more uniform heating rate (Mudgett, 1989). During heating, a temperature gradient results and heat is distributed throughout the product via conduction (Bakanowski and Zoller, 1984; McWilliams, 1989). Therefore, heating continues after the microwaves have ceased entering the product (Bakanowski and Zoller, 1984; McWilliams, 1989). This activity is referred to as standing time (Freeland-Graves and Peckham, 1987; McWilliams, 1989).

Microwave cookery is less time consuming than conventional oven preparation (Korschgen et al., 1976; Moore et al., 1980; Starrak and Johnson, 1982; Bakanowski and Zoller, 1984; Freeland-Graves and Peckham, 1984; McWilliams, 1989; Mudgett, 1989). This difference is due to the immediate generation of microwaves (McWilliams, 1989), instantaneous penetration of microwaves (Mudgett, 1989), and deeper penetration of the microwaves into food (Bakanowski and Zoller, 1984) resulting in heat generation.

A major contrast between microwave cookery and conventional cookery is that traditional microwave cookery is not able to brown foods (Freeland-Graves and Peckham, 1987; McWilliams, 1989; Mudgett, 1989). This difference is attributable to the lack of heat surrounding the product and the loss of heat from the surface of the product because the air inside the microwave remains cool which results in surface cooling of the food by the evaporation of moisture (Freeland-Graves and Peckham, 1987; Mudgett, 1989). Overcooking of the edges and corners of products may occur with microwave heating (Mudgett, 1989).

2.33 Relationship to Lipid Oxidation

Lipid oxidation, as measured by the TBA test, also appears to be affected by precooking and reheating. Penner and Bowers (1973) found that TBA values for microwave reheated pork were significantly greater than for freshly cooked samples. In agreement is Albrecht and Baldwin (1982) who found that microwave reheating caused higher TBA values compared to freshly roasted pork. Miller et al. (1985) observed larger TBA values for precooked, unseasoned pork chops, but they did not differ significantly from freshly broiled chops. According to Johnston and Baldwin (1980), precooked roast beef had higher TBA values than freshly roasted samples. In contrast, Campbell and Mandigo (1978) found higher TBA values for freshly cooked restructured pork patties than in the microwave reheated samples. However, Hsieh and Baldwin (1984) and Hwang et al. (1990) determined that lipid oxidation in beef was not affected by precooking.

2.34 Relationship to Tenderness

The effect of precooking on tenderness is not always consistent. Pork roasts cooked prior to frozen storage did not differ significantly in sensory panel tenderness scores from pork roasts cooked after frozen storage (Watts et al., 1948). Jones et al. (1987) and Campbell and Mandigo (1978) found that Warner-Bratzler shear values did not differ for precooked samples of whole muscle pork chops and restructured pork, respectively, compared to freshly cooked samples. However, Jones et al. (1987) found higher sensory panel tenderness scores indicating more tenderness for precooked pork roasts reheated in a water bath than those that were not precooked. Miller et al. (1985) found that freshly cooked pork chops were less tender because they had higher Warner-Bratzler shear values than precooked, unseasoned counterparts. Dahlinger and Lewis (1954) observed that precooked beef roasts were more tender as determined by the sensory panel, but the opposite effect was found from the Warner-Bratzler shear values. Less tender precooked restructured beef roasts were observed by Wiebe and Schmidt (1982). Montgomery et al. (1977) found precooked pork chops to have lower sensory panel tenderness scores as well as higher Warner-Bratzler shear values, indicating that precooking pork chops did not improve tenderness.

2.35 Relationship to Sensory Values

Juiciness appears to present a problem when pork is precooked or reheated. Watts et al. (1948) found that pork roasts precooked before freezing had higher juiciness sensory scores than roasts cooked after frozen storage. Miller et al. (1985) observed significantly higher sensory panel juiciness scores for precooked pork chops, but the moisture content was significantly lower when compared to freshly broiled chops. Penner and Bowers (1973) observed that microwave reheated pork had significantly lower sensory panel juiciness scores, as well as significantly less moisture, than freshly cooked samples. Montgomery et al. (1977) also found that pork chops precooked by a microwave or conventional oven were significantly less juicy than freshly broiled chops, as determined by the sensory panel. Campbell and Mandigo (1978) supported this observation by reporting that microwave reheated restructured pork had significantly lower sensory panel juiciness scores and significantly less moisture than samples that were not reheated. Johnston and Baldwin (1980) found less moisture in both conventionally and microwave reheated beef roasts than freshly roasted samples. Precooked restructured beef steaks also had significantly less moisture than freshly cooked steaks (Wiebe and Schmidt, 1982).

Fat content appears to remain constant in precooked samples. This measurement did not differ significantly in precooked whole pork muscle (Miller et al., 1985; Jones et al., 1987), precooked restructured pork (Campbell and Mandigo, 1978), or in precooked restructured beef (Wiebe and Schmidt, 1982).

Wilson et al. (1976) concluded that TBA numbers increase dramatically in cooked-refrigerated red meat compared to fresh cooked muscle. Tims and Watts (1958) and Cordray et al. (1986) observed that TBA values for cooked-refrigerated samples increased consistently during storage, while those for raw refrigerated samples remained relatively constant. Higher TBA values often indicate increased rancidity or warmed-over flavor (Tims and Watts, 1958; Sato and Hegarty, 1971). Because precooked samples have higher TBA values, they are more likely to exhibit more warmed-over flavor development and less desirable overall flavor. Johnston and Baldwin (1980) found that warmed-over flavor in roast beef significantly increases with reheating. In roast pork, warmed-over flavor was also significantly more intense with reheating compared to freshly roasted samples (Albrecht and Baldwin, 1982). Precooked pork chops had significantly lower sensory panel flavor scores than fresh broiled chops (Montgomery et al., 1977; Miller et al., 1985). However, no significant difference in sensory panel flavor scores was found with precooked pork roasts compared to conventionally cooked pork roasts (Jones et al, 1987) and precooked restructured pork patties compared to freshly frozen cooked restructured pork patties (Campbell and Mandigo, 1978).

2.4 STORAGE STABILITY

2.41 Objective Tenderness Measurements

Storage had different effects on Warner-Bratzler shear values in many studies. In precooked roast pork, Robson et al. (1989) found that increased storage time of up to eight days resulted in higher Warner-Bratzler shear values indicating a decrease in tenderness. The same result was found by Korschgen and Baldwin (1971) in precooked ham, however, the storage times were much longer (one, three, six months). Gokalp et al. (1978) also observed an increase in Warner-Bratzler shear values in raw beef stored for up to nine months. Even after three months there was a marked increase in Warner-Bratzler shear values in this study.

The opposite relationship between storage time and Warner-Bratzler shear values was found by Weakley et al. (1986). Fresh pork was stored and then cooked prior to analysis. Their results revealed that Warner-Bratzler shear values decreased after day zero for the remaining storage times of up to 14 days. This could be due to the effects of aging. Neutral proteases acted to break down myofilaments which in turn improved tenderness (Judge et al., 1989).

Several researchers also have concluded that storage time had no effect on Warner-Bratzler shear values (Law et al., 1967; Campbell and Mandigo, 1978; Jones et al., 1987; Paterson and Parrish, 1988). Jones et al. (1987) found no significant difference in Warner-Bratzler shear values in precooked pork roasts due to storage for up to 28 days. Precooked restructured pork patties also exhibited no significant change in Warner-Bratzler shear values with storage for up to six weeks (Campbell and Mandigo, 1978). The same result was found by Paterson and Parrish (1988) in precooked beef roasts. With storage for up to 45 days, there was no significant change in Warner-Bratzler shear values. Law et al. (1967) stored loin and top round beef steaks for intervals of zero, six, and nine months and found no significant change in Warner-Bratzler shear values in either cut due to storage.

2.42 Relationship to Sensory Traits

Sensory panel juiciness scores appeared not to be affected by storage time (Campbell and Mandigo, 1978; McDaniel et al., 1984; Marriott et al., 1987; Paterson and Parrish, 1988; Boles and Parrish, 1990). Boles and Parrish (1988) found no significant change in juiciness scores of precooked pork roasts in refrigerated storage for up to 28 days. The same results were observed by Campbell and Mandigo (1978) in precooked restructured pork patties stored frozen for up to six weeks. Marriott et al. (1987) found that juiciness scores for restructured pork in frozen storage for intervals of five and 56 days, were not affected by storage time. Precooked beef also exhibited no significant change in sensory panel juiciness scores when stored in refrigerated storage for 21 days (McDaniel et al., 1984) and 45 days (Paterson and Parrish, 1988).

However, in a study conducted by Robson et al. (1989), roast pork stored for up to eight days showed a significant decrease in sensory panel juiciness scores when compared to the samples that were freshly cooked. Law et al. (1967) found that raw beef in frozen storage for up to nine months and then subsequently cooked resulted in sensory panel juiciness scores that decrease significantly between six and nine months.

Boles and Parrish (1990) found that off-flavor and overall palatability of precooked pork roasts in refrigerated storage did not differ significantly during storage for up to 28 days. However, Albrecht and Baldwin (1982) concluded that storage was responsible for aroma and flavor changes in precooked pork. Warmed-over aroma scores increased significantly for precooked pork in refrigerated storage from storage day zero to day eight (Willemot et al., 1985).

In restructured precooked pork patties, Campbell and Mandigo (1978) found no significant change in flavor over a six week frozen storage period. Matlock et al. (1984) did, however, observe an increase in off-flavor in precooked frozen pork sausage patties with storage. They observed significantly more off-flavor at the storage time of two, four, and eight weeks than at day zero.

Rancid odor and rancid flavor scores were not significantly affected by refrigerated storage of up to 21 days in fresh pork (Igbinedion et al., 1983). In a study conducted by Marriott et al. (1987), no significant change in sensory panel flavor scores occurred among restructured pork patties in frozen storage for up to 56 days. In contrast to these results, Robson et al. (1989) found that off-odor and off-flavor increased while roast pork odor and flavor decreased with storage at both 1° C and 5° C. These changes occurred by day four in storage at 5° C and after day four at 1° C.

Sensory panel warmed-over flavor scores of precooked beef were not significantly affected by refrigerated storage for two and seven days in a study conducted by Hsieh and Baldwin (1984). McDaniel et al. (1984) found no significant differences in sensory panel flavor scores or overall acceptability scores in precooked beef stored for up to 21 days. Similar results were reported by Paterson and Parrish (1988). They found no significant change in sensory panel flavor scores of precooked beef stored for up to 45 days. In a study of fresh beef stored for up to nine months, Law et al. (1967) concluded that sensory panel flavor scores decreased significantly between six and nine months.

2.43 Effects on Appearance of Precooked Meat

Color and texture contribute to overall appearance. Color is one of the most important aspects of appearance (Clydesdale, 1976). There are two basic measurements that should be used when measuring meat color (Hunt, 1980). These are visual appraisal by the human eye and an instrumental analysis (Hunt, 1980).

One of the most commonly used techniques in determining color is the Hunter color meter (Clydesdale, 1969; Francis, 1971). With this measurement, L refers to lightness, a indicates redness (positive) and green (negative), and b indicates yellowness (positive) and blueness (negative) (Clydesdale, 1969; Francis, 1971).

In fresh meat, oxymyoglobin is most important because it contributes to the bright red color associated with fresh meat (Lawrie, 1991). In metmyoglobin the iron is oxidized and the meat is brown in color (Judge et al., 1989). This presents a problem in fresh meat because brown color is perceived by consumers as unacceptable (Judge et al., 1989). With cooked meat, brown globin haemichromogen is the main pigment involved (Lawrie, 1991). In this case, the brown pigment is associated with an acceptable product (Lawrie, 1991). The caramelization of carbohydrates and Maillard-type browning reactions between reducing sugars and amino groups also contribute to the formation of brown color in cooked meat (Lawrie, 1991).

Ockerman and Organisciak (1979) found that the visual acceptability of precooked beef in refrigerated storage did not differ significantly over a storage period of 10 days. Campbell and Mandigo (1978) observed that visual texture of precooked restructured pork did not differ over six weeks of storage. Similarly, McDaniel et al. (1984) found no difference in visual appearance scores of precooked beef over 21 days of storage. They also observed no significant change in color evaluation of precooked beef over the same storage period. However, Campbell and Mandigo (1978) found that color of precooked restructured steaks was rated higher by the sensory panel at zero weeks than at six weeks.

2.44 Effects on Microbial Aspects of Precooked Meat

Before a healthy animal is slaughtered, the edible tissues of the animal are essentially sterile (Niven, 1987). However, as the animal is skinned, the flesh becomes exposed to air, and consequently the microorganisms in it (Niven, 1987). Comminuted meats tend to have higher numbers of microorganisms than before particle size reduction due to the excessive handling of the various cuts that are used in making meat products and to the increased surface area resulting from comminution which increases the flora (Jay, 1986).

According to Banwart (1989), there are four major classes of microorganisms based on temperature for growth. These include psychrophilic, psychrotrophic, mesophilic, and thermophilic microorganisms. Psychrophilic microorganisms have an optimum temperature range for growth of 10 to 30° C with a minimum of -15 to 5° C and a maximum of 20 to 40° C. The optimum temperature range for growth of psychrotrophic microorganisms is 25 to 30° C with a minimum of -5 to 5° C and a maximum of 30 to 40° C. Mesophiles grow best at temperatures of 25 to 40° C and have a minimum temperature range for growth of 5 to 25° C and a maximum of 40 to 50° C. The optimum temperature range for growth of thermophiles is 45 to 65° C with a minimum of 35 to 45° C and a maximum of 60 to 90° C. All microorganisms have a unique temperature range for growth with their own specific minimum and maximum temperature. If the microorganism is exposed to heat at a temperature above its optimum for growth, there is a decline in the growth rate. As the maximum temperature is exceeded, the microorganism will be injured or die (Banwart, 1989).

Most meat products are held at refrigeration temperatures which favor the growth of psychrotrophs which have a maximum temperature range for growth of 30 to 40° C (Niven, 1987). Therefore, precooking meat to temperatures greater than 40° C injures these organisms. Emswiler et al. (1979) suggested that reheating precooked beef patties can further reduce microbial numbers.

Emswiler et al. (1979) found that precooked beef patties had lower aerobic plate counts than raw patties. They also found that the number of *Staphylococcus aureus* as detected by the most probable number technique could be significantly reduced by precooking. Robson et al. (1989) found that the growth of mesophiles and psychrotrophs in precooked pork was slow. They also observed low numbers (2.1 log number/g at 1° C and 2.8 log number/g at 5° C for mesophiles and 1.2 log number/g at 1° C and 2.7 log number/g at 5° C for psychrotrophs) after eight days of storage. Jones et al. (1987) observed less than 100 colonies per gram of tissue in precooked pork after storage for 21 days. They controlled contamination by precooking the samples after they had been vacuum packaged. However, McDaniel et al. (1984) found a numerical increase in mesophiles from 3.42 log number/g at seven days of storage to 6.87 log number/g after 14 days to 7.65 log number/g at 21 days of storage of precooked beef. They observed a similar trend with psychrotrophs. At seven days of storage the count was 3.07 log number/g which increased to 6.78 log number/g at 14 days and 7.52 log number/g at 21 days of storage.

2.5 VACUUM PACKAGING

Vacuum packaging significantly reduces that amount of oxygen in contact with the product (Hsieh and Baldwin, 1984;

Boles and Parrish, 1990; Hwang et al., 1990). By limiting the amount of contact the product has with oxygen, the amount of lipid oxidation can be controlled (Chiang et al., 1981; Gokalp et al., 1983; Hsieh and Baldwin, 1984; Matlock et al., 1984; Miles et al., 1986; Jones et al., 1987; Nolan et al., 1989; Boles and Parrish, 1990; Hwang et al., 1990). Matlock et al. (1984) found that rancidity development in precooked sausage patties could be reduced with vacuum packaging. They also observed less off-flavor in vacuum packaged than in PVC-wrapped samples as determined by sensory evaluation. Likewise, Nolan et al. (1989) found that cooked pork patties stored in vacuum packaging had less warmed-over flavor and more meaty aroma and flavor characteristics than those packaged in air. Vacuum packaging reduced rancidity development (Jones et al., 1987) and inhibited warmed-over flavor (Boles and Parrish, 1990) in precooked pork. Vacuum packaging has similar affects on precooked beef. Hsieh and Baldwin (1984) found that precooked beef stored in a casserole dish had more intense warmed-over flavor than samples that were vacuum packaged. Also, TBA values were lower in the vacuum packaged samples. The same results for precooked beef were found in a study conducted by Hwang et al. (1990). Vacuum packaged precooked beef had more meaty, less warmed-over flavor, and less oxidized flavors and aromas than air-packaged samples. TBA values were also lower for vacuum packaged samples. They also found that texture was not affected by packaging method.

Chiang et al. (1981) and Miles et al. (1986) found that vacuum packaging retarded lipid oxidation in raw restructured pork. Brewer et al. (1992) found that vacuum packaging resulted in the lowest TBA values of raw ground pork after 39 weeks of frozen storage when compared to polyvinyl chloride film, Saran Wrap, aluminum foil, and a combination of Saran Wrap and aluminum foil. They also observed that vacuum packaged raw ground pork stored for 39 weeks in frozen storage did not differ from fresh ground pork in rancid odor. Vrana et al. (1985) concluded that vacuum packaged pork chops had more desirable overall appearance, less surface discoloration, and less intense off-odor than those packaged in PVC film. Similarly, Smith et al. (1974) found that vacuum packaged pork had less surface discoloration with higher consumer acceptability than pork loins wrapped in PVC film. However, they observed no difference between packaging treatments on off-odor incidence after storage. Gokalp et al. (1983) found that TBA values for raw beef patties increased much more rapidly after 45 days of storage in non-vacuum packaged samples compared to those that were vacuum packaged. Vacuum packaged beef had more surface discoloration and less desirable overall appearance than samples packaged in polyethylene bags (Davis et al., 1977).

2.51 Microbial Aspects

Vacuum packaging with oxygen-impermeable material is important from a microbial viewpoint. Vacuum packaging protects color in cured meats (Urbain and Campbell, 1987) and inhibits the growth of aerobic microorganisms (Jones et al., 1987; Lundquist, 1987; Niven, 1987; Urbain and Campbell, 1987). Igbinedion et al. (1983) concluded that vacuum packaging had a favorable result on total aerobic plate counts and proteolytic psychrotroph counts of fresh pork compared to PVC film. They also found that lipolytic psychrotroph counts of vacuum packaged pork did not increase until after seven days of storage, and this count did not differ between 14 and 21 days; whereas the lipolytic psychrotroph counts of PVC film wrapped samples increased steadily from 0 to 21 days. Weakley et al. (1986) found similar results. They observed that total plate counts for vacuum packaged fresh pork loins were lower than parchment wrapped cuts after 14 days of storage. Higher bacterial counts were found for pork stored in polyethylene bags compared to those in vacuum packaging (Davis et al., 1977). Smith et al. (1974) found that pork loins packaged in PVC film had lower bacterial counts after seven days and combined storage times than vacuum packaged samples. In contrast to these results, Gokalp et al. (1978) found no significant difference between packaging methods in microbial counts of beef stored for up to nine months.

CHAPTER III

MATERIALS AND METHODS

Porcine samples were obtained from four U.S. No. 1 pork carcasses at the Virginia Polytechnic Institute and State University Meats Laboratory. Boneless whole muscle cuts were removed from the *M. longissimus thoracis et lumborum* from pork carcasses stored for 120 hours at 3° C. Bone and fat in excess of 0.6 cm was removed. Boneless chops were cut 1.9 cm thick. One half of the chops were put through a Ross blade tenderizer (Model T C7 00M, Ross Industries, Midland, Va.) once per side.

Restructured pork chops were manufactured from postrigor pork stored for 72 hours at 3° C using the muscles from the shoulder portion removed from the carcasses. Manufacture took place in a 12° C processing area. The lean portion comprised 60% of the formulation while the fatter component comprised 40% of the product. Particle size was reduced using a Hobart grinder (Model 4532, The Hobart Manufacturing Company, Troy, Ohio). The lean portion was ground using a 0.95 cm (3/8 inch) plate while the fat component was ground using a 0.48 cm (3/16 inch) plate. The formulation also contained 1% NaCl and 0.25% sodium tripolyphosphate based on the weight of the product which were mixed together for eight minutes in a Hobart mixer

(Model 998158, The Hobart Manufacturing Company, Troy, Ohio). The comminuted materials were stuffed using a tabletop stuffer (Koch Supplies Inc., Kansas City, Mo.) into 8.8 cm casings (EZ 6S X 30 light PS, Viskase Corporation, Chicago, Ill.) and placed in -20° C storage for 12 hours. The samples were then tempered to -5° C using a Bacteriological Incubator (Fischman Co., Philadelphia, Pa.). Upon tempering, the logs were shaped using a Ross press (Model 720, Ross Industries, Midland, Va.). After pressing, the samples were cut using a Hobart meat saw (Model 5216, The Hobart Manufacturing Company, Troy, Ohio). Both whole muscle cuts and the restructured chops were vacuum packaged (Inauen Maschinen VC999/01, Inauen Maschinen Ag, Herisau, Switzerland) in moisture impermeable bags (type B550T, Cryovac Division W.R. Grace & Co., Duncan, S.C.) and stored at 2° C for 2, 15, and 21 days.

3.1 Sampling and Storage

Whole boneless pork chops and the restructured samples were randomly assigned to sensory evaluation or objective testing. The treatments included three cooking methods [conventional (CO), microwave (MW), and conventionally precooked/microwave reheated (CMW)], blade tenderized or not blade tenderized for whole muscle cuts, and three storage periods (2, 15, and 21 days). Conventionally precooked/microwave reheated chops were also assigned to visual evaluation for the three storage periods.

Samples that were not precooked were vacuum packaged as previously described and placed in dark storage at 2° C for 2, 15, and 21 days. The remaining samples were precooked to an internal temperature of 60° C to provide a product that was partially cooked with less potential for an oxidative off-flavor in a conventional electric oven (Model RDE-20S, Frigidaire, Division, Dayton, Ohio) preheated to 200° C. Chops were turned at an internal temperature of 37.8° C for even cooking on both sides. Temperature of the chops was monitored using an Omega Digital Thermometer (Model 2160-A-7, Omega Engineering, Inc., Stamford, Conn.) with copper-constantan thermocouple wires which were placed in the geometrical centers of the chops. The chops were then cooled to ambient temperature, vacuum packaged (as for non-precooked chops) and placed in dark storage at 2° C for 2, 15, and 21 days.

3.2 Visual and Instrumental Color Determinations

Vacuum packaged precooked chops allotted for visual and instrumental color determinations were displayed on each of the storage days in a 4° C display case (Tyler Commercial Refrigerator and/or Freezer CG88M, Tyler Refrigeration Corp., Niles, Michigan) and evaluated under 1076 lux (100 footcandles) of cold white fluorescent light (Philips, 30 watts) for color and overall appearance by seven trained panel members using an eight point scale (1=very undesirable and 8=very desirable). Training consisted of three 45-minute sessions familiarizing panelists with the attributes being evaluated (AMSA, 1978). Training samples were held under conditions similar to that of the actual panel. The same chops used for visual evaluation were objectively measured for color using a Minolta CR-200 Chroma Meter (Minolta Camera Co., Ltd., Osaka, Japan). The instrument was calibrated using a standard Minolta calibration plate (CIE L^* 97.91, a^* -0.70, b^* +2.44). Values were obtained from five areas on each chop which were averaged to represent the whole sample.

3.3 Sensory Evaluation

On the appropriate storage day of 2, 15, or 21, 12 whole and 6 restructured pork chops were prepared. Conventionally cooked chops were heated to an internal temperature of 70° C in a conventional electric oven preheated to 200° C. Chops were turned at an internal temperature of 37.8° C for even cooking on both sides (temperature monitored as for precooking). Chops assigned to microwave cookery were placed on a paper towel on a plastic microwavable safe dish and cooked to an internal temperature of approximately 70° C. The power level setting for the microwave oven (Model M41A-7P, 120 volts, Magic Chef, Inc., Anniston, Alabama) was 6. Internal temperature was observed using a thermometer. Precooked chops were reheated in the microwave oven for approximately 1.5 minutes for whole cuts and 4.0 minutes for restructured chops to an internal temperature of approximately 70° C similarly to microwave cooked samples. Twelve to 14 cores 1.27 cm in diameter were removed from each chop. One core for each panel member was stored in a sealed plastic bag and placed in a water bath (54° C) until evaluation (20 minutes).

Seven trained panel members evaluated the samples for juiciness, texture, and overall flavor using an eight point scale (1=very undesirable and 8=very desirable). Three 45-minute training sessions were conducted to familiarize the panel members with the attributes being evaluated (AMSA, 1978). Training samples varied in juiciness, texture, and overall flavor. Chops were evaluated in sensory booths under red light. Apple slices and tap water were used to cleanse the palate between each sample. Three digit coding was used to code the samples which were presented in random order.

3.4 Warner-Bratzler Shear Determinations

Five to seven cores taken from samples cooked for sensory evaluation were used to determine Warner-Bratzler shear values. An Instron (Model 1011, Instron Corp., Canton, Mass.) was used to measure peak force required to shear through the core. The speed of the crosshead was 200mm/min. A 50 kg load cell was used with a load range of 20% (10 kg) for whole muscle samples and a load range of 10% (5 kg) for restructured samples. The cores were sheared at room temperature once per core through the center cross section. The readings were averaged to represent the whole chop.

3.5 Chemical Determinations

Percentage moisture was determined following AOAC (1990) procedures on duplicate 3 g samples from each chop. Goldfisch extraction was used to determine percentage fat (AOAC, 1990). Malonaldehyde content (TBA value) was determined following the procedure used by Ockerman (1985) with the addition of 5 ml of 0.5% PG and EDTA during blending (Rhee, 1978).

3.6 Statistical Analysis

Data were analyzed using Analysis of Variance (ANOVA) and the General Linear Model (GLM) procedures of the Statistical Analysis System (1987). Sensory panel scores were evaluated as a split-plot design. The Least Significant Difference procedure of SAS (1987) was used to separate mean values if the model contained significant differences (α=0.05). All other data was evaluated using a completely randomized block design.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Treatment Effects on Chemical Analyses

4.11 Effect of Blade Tenderization on Whole Muscle Cuts

Percentage moisture and fat and TBA values of blade tenderized samples did not differ (P>0.05) from control samples (Table 1). Blade tenderization could possibly cause moisture loss through the rupture of cells by the blades. Blade tenderized samples did have numerically lower moisture contents, but this was not significant. Blade tenderization would not be expected to affect fat content because it is a mechanical procedure that should not change the content of fat. TBA values might be expected to increase due to blade tenderization because of increased surface area that can interact with oxygen.

4.12 Effect of Cooking Method

4.121 Moisture Content

Cooking method did not significantly (P>0.05) affect moisture content of whole muscle samples or restructured chops (Table 2). Other research has shown lower moisture content in precooked whole pork compared to freshly cooked samples

Table 1 - Effects of blade tenderization on the chemical analyses of pork longissimus muscle

	Blade Tenderization		
	blade tenderized	not tenderized	Standard error
Chemical analyses			
Moisture (%)	56.77[a]	56.87[a]	0.71
Fat (%)	14.75[a]	13.25[a]	1.42
Fat (%) - raw	8.25[a]	9.12[a]	0.91
TBA value	0.21[a]	0.20[a]	0.01

[a]Means within the same row bearing like superscripts are not different (P>0.05)

Table 2 - Effects of cooking method on the chemical analyses of pork longissimus muscle and restructured chops

	Cooking Method[d]			
	CO	MW	CMW	Standard error
Whole muscle:				
Chemical analyses				
Moisture (%)	57.61[a]	53.85[a]	54.24[a]	1.16
Fat (%)	8.23[a]	12.60[a]	11.18[a]	1.88
TBA value[e]	0.12[c]	0.18[b]	0.31[a]	0.02
Restructured:				
Chemical analyses				
Moisture (%)	59.02[a]	58.20[a]	55.92[a]	0.07
Fat (%)	15.35[a]	14.75[a]	14.25[a]	0.79
TBA value[f]	0.11[b]	0.25[a]	0.23[a]	0.03

[abc]Means within the same row bearing like superscripts are not different (P>0.05)
[d]Cooking method: CO=conventional oven cookery, MW=microwave oven cookery, CMW=conventionally precooked/microwave reheated
[e]Cooking method*storage period interaction (Table 4)
[f]Cooking method*storage period interaction (Table 5)

(Penner and Bowers, 1973; Miller et al., 1985) as well as lower moisture content in precooked restructured pork patties (Campbell and Mandigo, 1978). A greater loss of moisture in MW samples compared to CO may be due to the lack of the denaturation of surface proteins that occurs when meat is cooked in a conventional oven. The proteins coagulate and cause the surface of the meat to become rigid, trapping moisture in the product (Judge et al., 1989).

4.122 Fat Content

Cooking method had no effect (P>0.05) on fat content of either whole muscle cuts or restructured chops (Table 2). This is in agreement with Miller et al. (1985) who found no difference (P>0.05) in fat content of whole muscle pork cuts due to cooking method. Furthermore, Campbell and Mandigo (1978) observed no difference (P>0.05) in fat content of restructured pork patties due to cooking method.

4.123 TBA Values

CMW samples had the highest (P<0.05) TBA values for whole muscle samples (Table 2). CO samples had the lowest (P<0.05) TBA values while MW samples differed (P<0.05) from both CO and CMW samples. This increase from CO to MW to CMW is illustrated in Figure 1. Penner and Bowers (1973) agreed with this observation since they found that precooked pork had

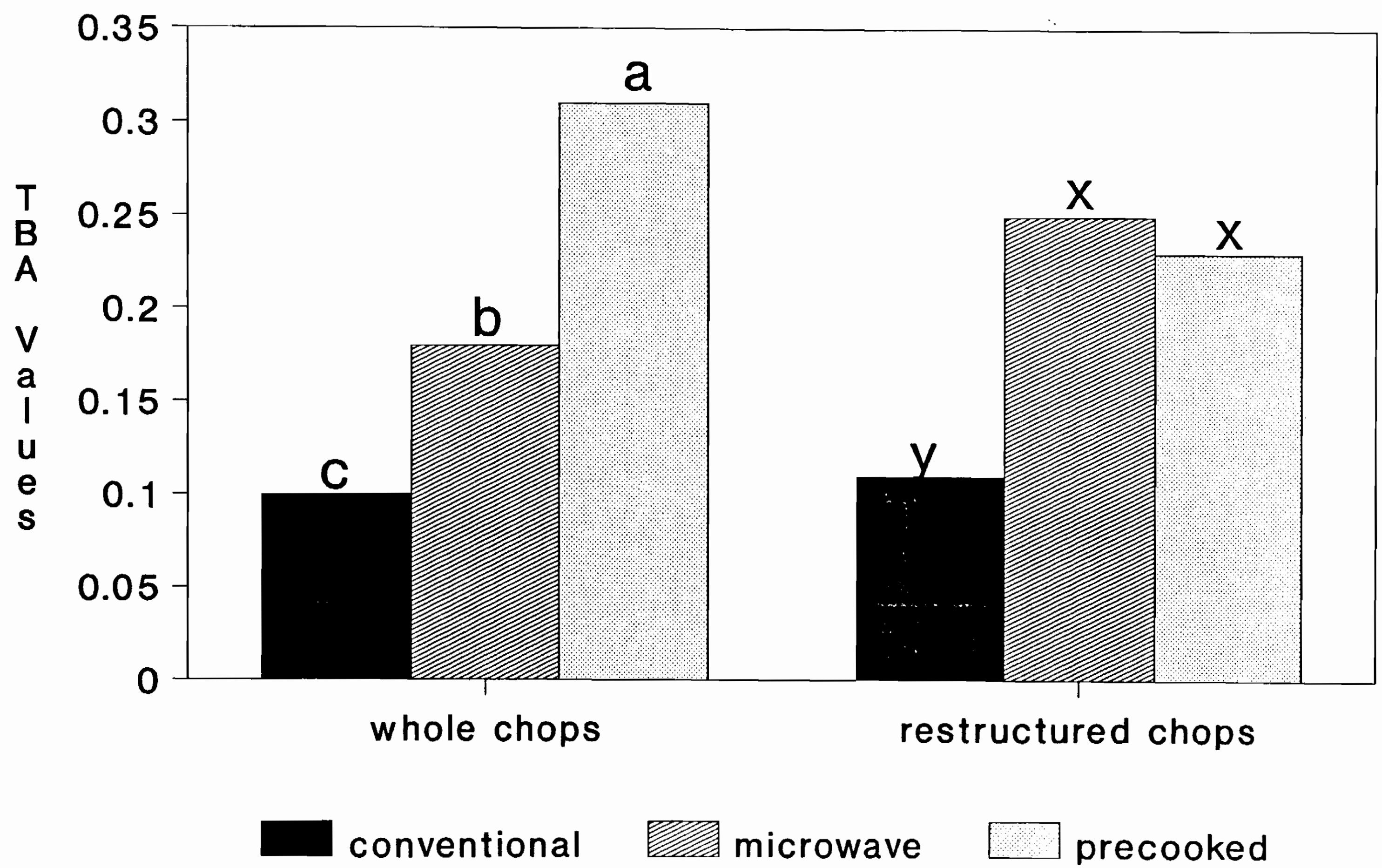


Figure 1. Effect of cooking method on TBA values of whole muscle and restructured pork chops
[abc]bars with like letters within a muscle cut are not different (P>0.05)
[xy]bars with like letters within a muscle cut are not different (P>0.05)

higher (P<0.05) TBA values than freshly cooked samples. Albrecht and Baldwin (1982) also reported that precooked/ reheated roast pork had higher (P<0.05) TBA values than freshly roasted samples. This can be explained by the catalytic effect of heat on lipid oxidation (Penner and Bowers, 1973). Also, Igene et al. (1979) suggest that lipid oxidation is accelerated due to the release of iron that occurs upon cooking.

Restructured CO samples had the lowest (P<0.05) TBA values. CMW and MW samples did not differ (P>0.05) from each other. Campbell and Mandigo (1978) found that conventionally reheated restructured pork patties had higher TBA values than freshly cooked patties while microwave reheated patties had lower TBA values than freshly cooked samples.

Precooked restructured chops had numerically lower TBA values than precooked whole muscle chops. It appears that precooking causes the phosphate to act to inhibit oxidation. Figure 1 illustrates the effect of cooking method on TBA values.

In both restructured and whole muscle samples, CMW TBA values were higher (P<0.05) than those for CO samples. The second exposure to heat causes this increase (Penner and Bowers, 1973). Also, MW samples for both restructured and whole muscle cuts had higher (P<0.05) TBA values than CO samples. This may be due to the variation in heating rates which may cause differences in thermal breakdown products. Research results have not been identified which compare TBA values of conventionally cooked meat to microwave cooked meat.

4.13 Effect of Storage Period

4.131 Moisture Content

For whole muscle cuts, moisture content of samples stored for 2 and 15 days did not differ ($P>0.05$) from each other (Table 3). However, day 21 samples had less ($P<0.05$) moisture than those for the other two storage periods. This could be explained by a cooking method*storage period interaction ($P<0.05$) (Appendix Table 11). CO samples had less ($P<0.05$) moisture at day 21 than at day 2 and day 15. CMW samples had less ($P<0.05$) moisture at day 21 than at day 2.

Moisture content of restructured chops for the three storage periods (2, 15, 21 days) did not differ ($P>0.05$) (Table 3). These results agree with those of Campbell and Mandigo (1978) who observed no effect of storage for up to six weeks on moisture content of precooked restructured pork patties. This could be due to the addition of sodium chloride in the formulation. According to Judge et al. (1989), the exchange of monovalent ions such as sodium for divalent ions on protein chains can improve water binding capacity.

Table 3 - Effects of storage on the chemical analyses of pork longissimus muscle and restructured chops

	Storage period (days)			
	2	15	21	Standard error
Whole Muscle:				
Chemical analyses				
Moisture (%)	57.83[a]	57.83[a]	54.81[b]	0.87
Fat (%)[c]	8.35[a]	7.75[a]	9.95[a]	1.11
TBA value[d]	0.16[b]	0.19[b]	0.26[a]	0.02
Restructured:				
Chemical analyses				
Moisture (%)	58.12[a]	56.78[a]	58.23[a]	0.78
Fat (%)[c]	12.85[b]	14.15[b]	17.05[a]	0.35
TBA value[e]	0.12[b]	0.18[b]	0.28[a]	0.03

[ab]Means within the same row with like superscripts are not different ($P>0.05$)
[c]Analysis done on raw samples only
[d]Cooking method*storage period interaction (Table 4)
[e]Cooking method*storage period interaction (Table 5)

4.132 Fat Content

No differences (P>0.05) in fat content over the three storage periods (Table 3) were observed for the raw whole muscle cuts. Fat content of raw restructured samples on day 21 was higher (P<0.05) than for days 2 and 15 (Table 3). Day 15 samples contained numerically higher fat content than those from day 2, but the difference was not significant (P>0.05). The increase at 21 days can be accounted for by experimental error and a possible loss of moisture to concentrate fat that was present.

4.133 TBA Values

The effect of storage on TBA values of both whole and restructured cuts is illustrated in Figure 2. Whole muscle samples stored for 21 days had the largest (P<0.05) TBA values (Table 3). Day 2 and day 15 samples did not differ (P>0.05) from each other due to storage. There was a cooking method*storage period interaction (P<0.05) for CO and CMW whole muscle samples (Table 4). The TBA value for day 21 CO chops was higher (P<0.05) than for days 2 and 15. For CMW chops, the TBA values increased (P<0.05) from day 2 to day 15 to day 21. CMW samples were higher (P<0.05) than CO and MW chops at all storage periods. This observation can be explained by the effects of cooking method. It has been found that precooked samples experience more oxidative rancidity

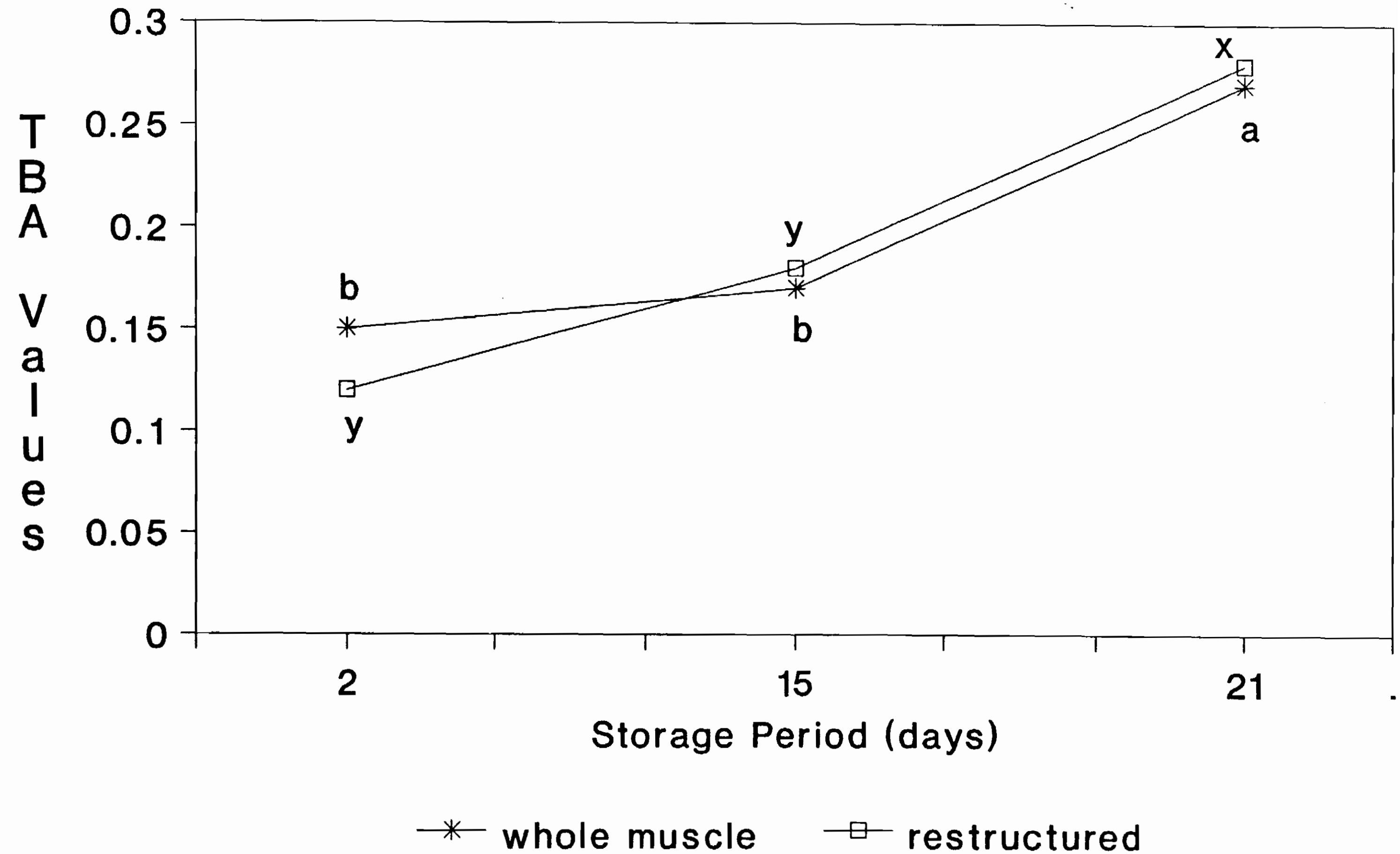


Figure 2. Effect of storage on TBA values of whole and restructured pork chops
[ab] points with like letters are not different (P>0.05)
[xy] points with like letters are not different (P>0.05)

Table 4 - Interaction[d] of cooking method and storage period on TBA values of pork longissimus muscle

	Cooking Method[c]			
	CO	MW	CMW	Standard error
Storage Period				
2 days	0.09^{by}	0.15^{ay}	0.23^{cx}	<0.03
15 days	0.05^{bz}	0.19^{ay}	0.32^{bx}	<0.03
21 days	0.21^{ay}	0.20^{ay}	0.38^{ax}	<0.03

[abc]Means bearing like superscripts within a column are not different (P>0.05)
[d]Interaction is significant (P<0.05)
[c]Cooking method: CO=conventional cookery, MW=microwave cookery, CMW=conventionally precooked/microwave reheated
[xyz]Means bearing like superscripts within a row are not different (P>0.05)

(Penner and Bowers, 1973; Albrecht and Baldwin, 1982) than those without this treatment. TBA values of CO and MW chops did not differ (P>0.05) from each other at day 2 or day 21. Witte et al. (1970) observed increases in TBA values of raw pork in refrigerated storage over a period of seven days. However, Igbinedion et al. (1983) observed no effect of storage time on TBA values of fresh pork chops in refrigerated storage for up to 21 days.

Restructured samples exhibited the same pattern as for whole cuts (Table 3). Day 21 samples had larger (P<0.05) TBA values than those stored for 2 and 15 days which did not differ (P>0.05) from each other. However, this observation does not agree with research conducted by Campbell and Mandigo (1978) who found an increase (P<0.05) in TBA values of restructured pork patties from 0 to 14 days of storage. There was a cooking method*storage period interaction (P<0.05) for restructured samples (Table 5). TBA values for MW samples did not differ (P>0.05) for days 2 and 15. TBA values for CMW at day 15 did not differ (P>0.05) from those at days 2 and 21.

4.2 Effect of Treatment on Color and Appearance

4.21 Effect of Blade Tenderization of Whole Muscle Cuts

Blade tenderization did not affect (P>0.05) Minolta L^*,

Table 5 - Interaction[c] of cooking method and storage period on TBA values of restructured pork chops

	Cooking Method[d]			
	CO	MW	CMW	Standard error
Storage Period				
2 days	0.09^{ax}	0.09^{bx}	0.18^{bx}	<0.04
15 days	0.13^{ax}	0.18^{bx}	0.24^{abx}	<0.04
21 days	0.10^{az}	0.48^{ax}	0.27^{ay}	<0.04

[ab]Means bearing like superscripts within a column are not different (P>0.05)
[c]Interaction is significant (P<0.05)
[d]Cooking method: CO=conventional cookery, MW=microwave cookery, CMW=conventionally precooked/microwave reheated
[xyz]Means bearing like superscripts within a row are not different (P>0.05)

a^*, or b^* values or the visually evaluated traits of color and overall appearance (Table 6). The color change that occurs in cooked meat is due to a chemical reaction between reducing sugars and amino groups (Lawrie, 1991). Blade tenderization is a physical process performed to tenderize meat and does not interfere with these chemical components. Therefore, blade tenderization may not affect the color.

4.22 Effect of Storage Period

Storage of whole muscle cuts for 21 days resulted in lower ($P<0.05$) CIE L^* values than for samples stored for 2 days (Table 7). Storage for 15 days did not differ ($P>0.05$) from the other periods. The CIE a^* and b^* values did not differ ($P>0.05$) between days of storage. Samples stored for two days had higher ($P<0.05$) visual color evaluation scores than for the other storage days which did not differ ($P>0.05$) from each other. However, all scores were in the slightly desirable to moderately desirable range. Overall appearance was not affected ($P>0.05$) by storage time. Similarly, with precooked beef, visual appearance did not differ over 21 days of storage (McDaniel et al., 1984).

Storage period did not affect ($P>0.05$) CIE L^*, a^*, or b^* values, visual color, or overall appearance of restructured chops (Table 7). The samples were cooked, vacuum packaged,

Table 6 - Effects of blade tenderization on the color and appearance of precooked pork longissimus muscle and restructured chops

	Blade Tenderization		
	blade tenderized	not tenderized	Standard error
CIE			
L^*	67.29[a]	67.73[a]	0.31
a^*	6.97[a]	7.44[a]	0.34
b^*	11.07[a]	11.08[a]	0.14
Visual trait[b]			
color	6.07[a]	5.89[a]	0.07
overall appearance	6.00[a]	5.86[a]	0.07

[a]Means within the same row bearing like superscripts are not different (P>0.05)
[b]Visual trait: color, overall appearance: 1=very undesirable, 8=very desirable

Table 7 - Effects of storage period on the color and appearance of precooked pork longissimus muscle and restructured pork chops

	Storage period (days)			
	2	15	21	Standard error
Whole Muscle:				
CIE				
L^*	68.42[a]	67.35[ab]	66.76[b]	0.38
a^*	6.72[a]	7.22[a]	7.69[a]	0.41
b^*	11.10[a]	11.13[a]	11.01[a]	0.17
Visual trait[c]				
color	6.20[a]	5.86[b]	5.89[b]	0.09
overall appearance	5.98[a]	5.86[a]	5.95[a]	0.09
Restructured:				
CIE				
L^*	52.10[a]	52.73[a]	53.79[a]	0.45
a^*	8.77[a]	8.91[a]	8.92[a]	0.24
b^*	10.74[a]	10.75[a]	10.59[a]	0.17
Visual trait[c]				
color	5.59[a]	5.71[a]	5.93[a]	0.15
overall appearance	5.73[a]	5.64[a]	5.96[a]	0.13

[ab]Means within the same row bearing like superscripts are not different (P>0.05)
[c]Visual trait: color, overall appearance: 1=very undesirable, 8=very desirable

and stored at 2° C with limited exposure to light. With these controlled conditions, the color and appearance of samples did not change during storage.

4.3 Effect of Treatment on Objective Tenderness Measurements

4.31 Effect of Blade Tenderization on Whole Muscle Cuts

Blade tenderized chops were not different (P>0.05) in peak force values (2.92 kg) than non-blade tenderized (2.93 kg) chops (Appendix Table 12). This technique is done to break down connective tissue (Schmidt, 1988). Most pigs, however, are slaughtered at a young age and connective tissue plays only a minor role in tenderness (Barton-Gade et al., 1988). Therefore, blade tenderizing pork may not affect Warner-Bratzler shear force values.

4.32 Effect of Cooking Method

Warner-Bratzler shear force values for CO whole muscle samples did not differ (P>0.05) from CMW chops, while the MW samples required the most (P<0.05) force but did not differ from CMW samples (Table 8). Overcooking of MW samples may have occurred resulting in higher Warner-Bratzler shear values than CO samples. This is in agreement with Jones et al. (1987) who concluded that Warner-Bratzler shear values of precooked pork chops did not differ (P>0.05) from freshly

Table 8 - Effects of cooking method on the objective tenderness measurement of pork longissimus muscle and restructured pork chops

	Cooking Method[c]			
	CO	MW	CMW	Standard error
Whole Muscle:				
Objective tenderness				
Peak force (kg)	2.77[b]	3.09[a]	2.91[ab]	0.07
Restructured:				
Objective tenderness				
Peak force (kg)	0.73[a]	0.79[a]	0.74[a]	0.02

[ab]Means within the same row bearing like superscripts are not different (P>0.05)
[c]Cooking method: CO=conventional oven cookery, MW=microwave oven cookery, CMW=conventionally precooked/microwave reheated

cooked samples. However, others have encountered contradicting results. Montgomery et al. (1977) observed increased (P<0.05) Warner-Bratzler shear values with precooked pork samples compared to the freshly broiled. Miller et al. (1985) found that freshly cooked pork chops had higher (P<0.05) Warner-Bratzler shear values than precooked samples.

Peak force values of restructured samples were unaffected (P>0.05) by cooking method (Table 8). The addition of salt may account for this. Salt is a very effective myofibrillar protein solubilizer. It combines with naturally occurring moisture to for a brine which solubilized the proteins (Mandigo, 1986). These results agree with those of Campbell and Mandigo (1978) who also found that peak force values of precooked restructured pork patties did not differ (P>0.05) from patties that were not reheated.

4.33 Effect of Storage Period

For whole muscle cuts, day 15 peak force values did not differ (P>0.05) from those of day 2 and day 21 (Table 9). Day 21 values were lower (P<0.05) than for day 2. Jones et al. (1987) found no difference (P>0.05) in Warner-Bratzler shear force values of conventionally cooked and precooked pork roasts stored for up to 28 days. Weakley et al. (1986) however, observed decreases (P<0.05) in Warner-Bratzler shear force values of fresh pork loins over 14 days of storage.

Table 9 - Effects of storage period on the objective tenderness measurement of pork longissimus muscle and restructured chops

	Storage period (days)			
	2	15	21	Standard error
Whole Muscle:				
Objective tenderness				
Peak force (kg)	3.05[a]	2.94[ab]	2.78[b]	0.07
Restructured:				
Objective tenderness				
Peak force (kg)	0.76[a]	0.78[a]	0.72[a]	0.02

[ab]Means within the same row bearing like superscripts are not different (P>0.05)

There was a lack of significance (P>0.05) with a cooking method and storage period interaction with whole muscle cuts (Table 10). Storage period affected only CMW chops. Day 21 values were lower (P<0.05) than day 2. Day 15 results did not differ (P>0.05) from day 2 or day 21. The trend for the CMW samples may be due to experimental variation.

Storage time had no affect (P>0.05) on peak force values of restructured samples (Table 9). This can be accounted for by the addition of salt and sodium tripolyphosphate to the formulation. The combination of these ingredients solubilize myofibrillar proteins by breaking actin and myosin bonds (Schmidt, 1988).

4.4 Effect of Treatment on Sensory Evaluation

4.41 Effect of Blade Tenderization of Whole Muscle Cuts

The effect of blade tenderization on sensory traits is illustrated in Figure 3. Blade tenderized samples did not differ (P>0.05) from non-blade tenderized cuts in juiciness and overall flavor scores. A lower juiciness score for blade tenderized samples would be expected because some moisture will be released when the muscle is punctured. Blade tenderized samples did have numerically lower juiciness scores, but the difference was not significant (P>0.05). Flavor is due to chemical compounds formed during cooking.

Table 10 - Interaction[c] of storage period and cooking method on the objective tenderness measurement[d] of pork longissimus muscle

	Cooking Method[e]			
	CO	MW	CMW	Standard error
Storage Period:				
2 days	2.93[ax]	3.11[ax]	3.12[ax]	0.12
15 days	2.74[ay]	3.19[ax]	2.89[abxy]	0.12
21 days	2.66[ax]	2.98[ax]	2.71[bx]	0.12

[ab]Means bearing like superscripts within a column are not different (P>0.05)
[c]Interaction is not significant (P>0.05)
[d]Peak force (kg)
[e]Cooking method: CO=conventional cookery, MW=microwave cookery, CMW=conventionally precooked/microwave reheated
[xy]Means bearing like superscripts within a row are not different (P>0.05)

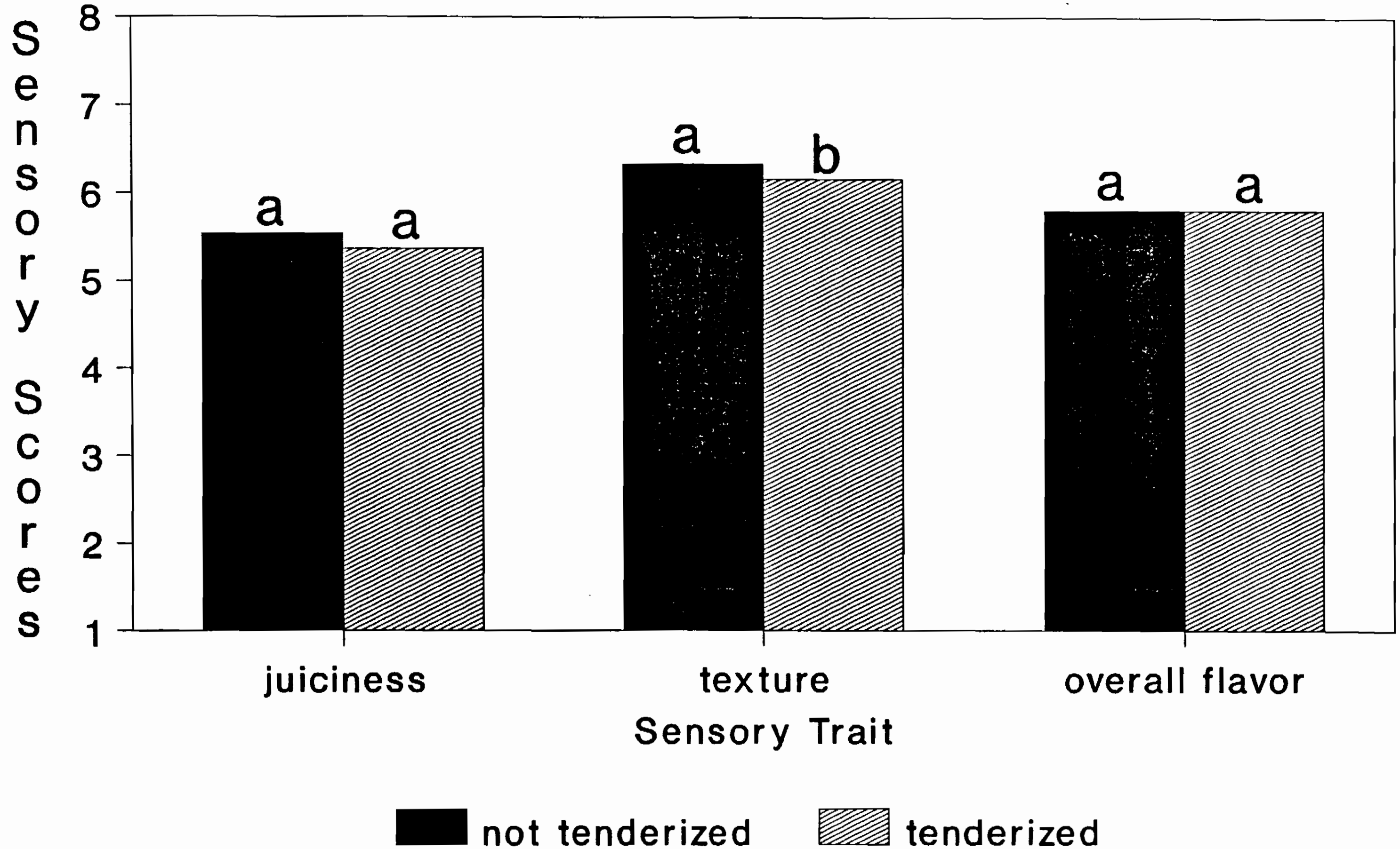


Figure 3. Effect of blade tenderization of whole muscle cuts on sensory traits

[ab]bars with like letters within a given sensory trait are not different (P>0.05)

Blade tenderization is a physical procedure done before cooking and may not affect the chemical compounds that contribute to flavor. If samples are improperly handled, blade tenderization may play a role in undesirable flavor development.

Blade tenderized samples received lower (P<0.05) sensory texture scores than non-blade tenderized samples. However, the mean score was in the moderately desirable range. This slightly lower texture score of blade tenderized samples may be due to the blade tenderizing causing a change in texture that is not characteristic of pork. The texture may not have been as firm as the panelists would have found desirable.

4.42 Effect of Cooking Method

CO whole muscle samples rated the highest (P<0.05) in juiciness scores, while CMW samples had the lowest (P<0.05) juiciness scores. CMW samples did not differ (P>0.05) from MW samples in texture scores. MW samples were less (P<0.05) juicy than CO samples but juicier (P<0.05) than CMW samples. The effect of cooking method on sensory traits can be seen in Figure 4. These results agree with those of Penner and Bowers (1978) who found that freshly cooked pork had higher (P<0.05) juiciness scores than precooked/reheated samples. Montgomery et al. (1977) also found that freshly broiled pork chops had higher (P<0.05) juiciness scores than precooked chops.

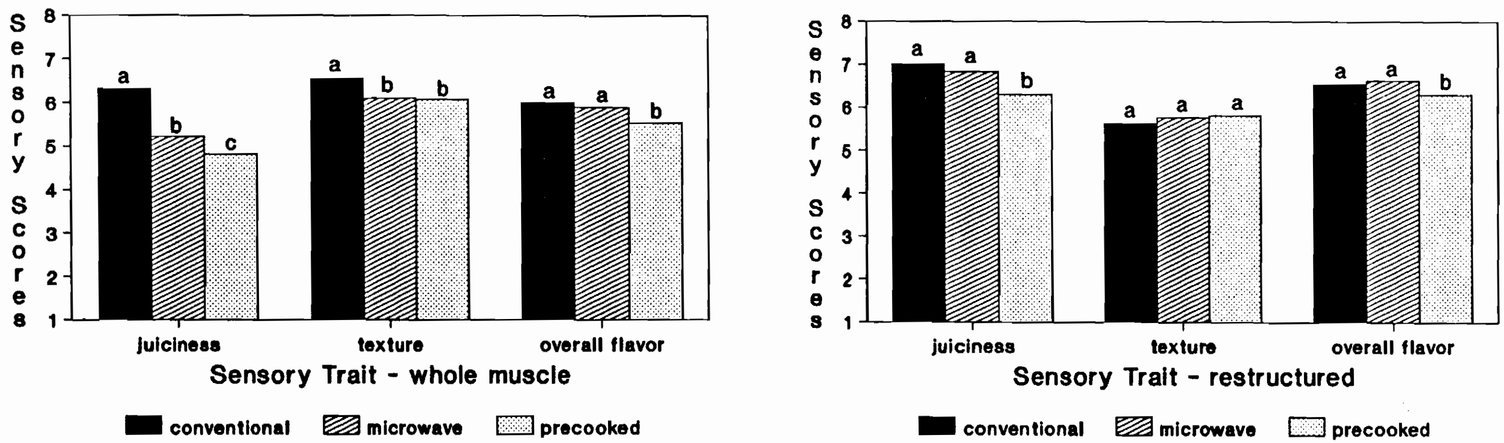


Figure 4. Effect of cooking method on sensory traits of whole muscle and restructured cuts

[ab] bars with like letters within a given sensory trait are not different ($P>0.05$)

CMW restructured chops were the least (P<0.05) juicy. This observation was attributable to the CMW samples being heated twice. There would have been a loss of moisture with the first heating in the conventional oven as well as with the second heating the microwave oven. CO and MW restructured samples, however, did not differ (P>0.05) in juiciness from each other. The effects of cooking method on sensory traits of restructured samples are presented in Figure 4. Similar results were obtained by Campbell and Mandigo (1978) who found that precooked/microwave reheated restructured pork patties had lower (P<0.05) juiciness scores than chops that were not precooked and reheated.

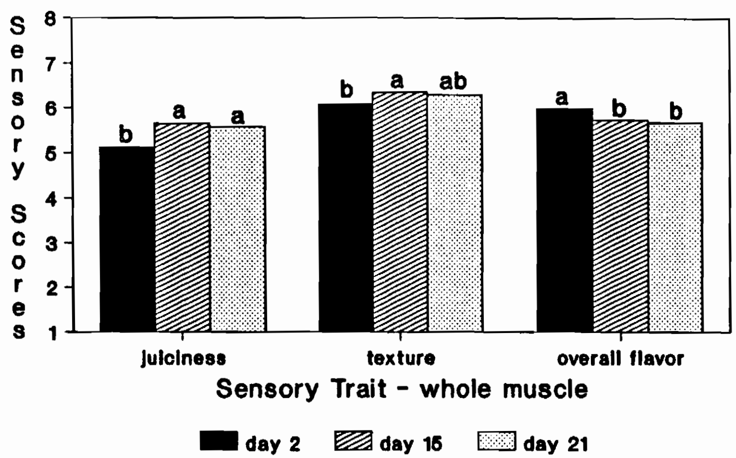
Restructured chops did not differ (P>0.05) in texture scores due to cooking method. The uniformity in composition and size of restructured samples may have caused this similarity in texture among cooking methods.

CMW whole muscle samples were rated lowest (P<0.05) in overall flavor. This observation agrees with a study conducted by Montgomery et al. (1977) in which they found that freshly broiled pork loins had higher (P<0.05) sensory panel flavor scores than precooked samples. Miller et al. (1985) also discovered that precooking pork chops resulted in lower (P<0.05) flavor scores. CO samples and MW samples did not differ (P>0.05) from each other in overall flavor. However, all of the flavor scores were between slightly desirable and moderately desirable.

Similar results were obtained for restructured chops. CMW samples had the lowest (P<0.05) mean overall flavor score. This does not agree with the results of a study conducted by Campbell and Mandigo (1978) who found no difference (P>0.05) in sensory panel flavor scores of precooked compared to freshly cooked restructured pork patties. CO samples and MW samples did not differ (P>0.05) from each other in overall flavor. However, all of the flavor scores were moderately desirable to desirable.

4.43 Effect of Storage Period

The effect of storage period on sensory traits is illustrated in Figure 5. Whole muscle samples stored for 2 days were the least (P<0.05) juicy and had the highest (P<0.05) overall flavor scores as well as the lowest (P<0.05) texture rating. Day 15 and day 21 samples did not differ (P>0.05) from each other in juiciness and overall flavor scores. There is are cooking method*storage period interactions (P<0.05) for both juiciness (Figure 6) and overall flavor (Figure 7). Day 21 chops did not differ (P>0.05) in texture scores from those stored for 2 and 15 days. However, all of the sensory scores were slightly desirable to moderately desirable. These data indicate that optimum texture and juiciness scores are obtained at 15 to 21



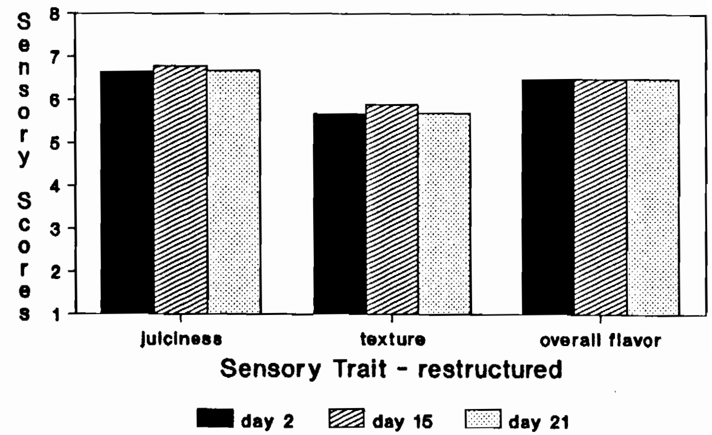


Figure 5. Effect of storage on sensory traits of whole muscle and restructured cuts

[ab] bars with like letters within a given sensory trait are not different ($P>0.05$)

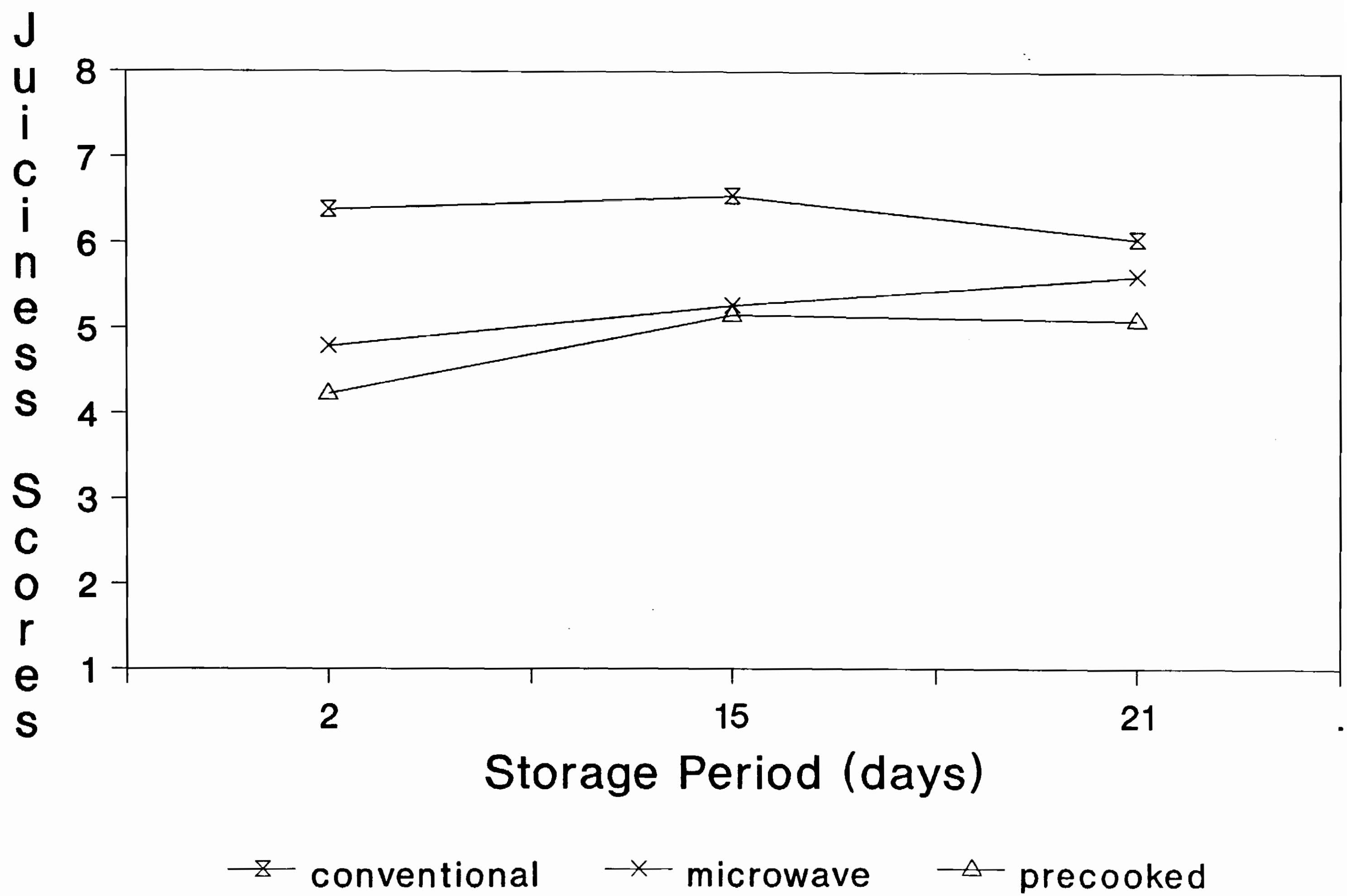


Figure 6. Cooking method * storage period interaction on juiciness scores of whole muscle cuts

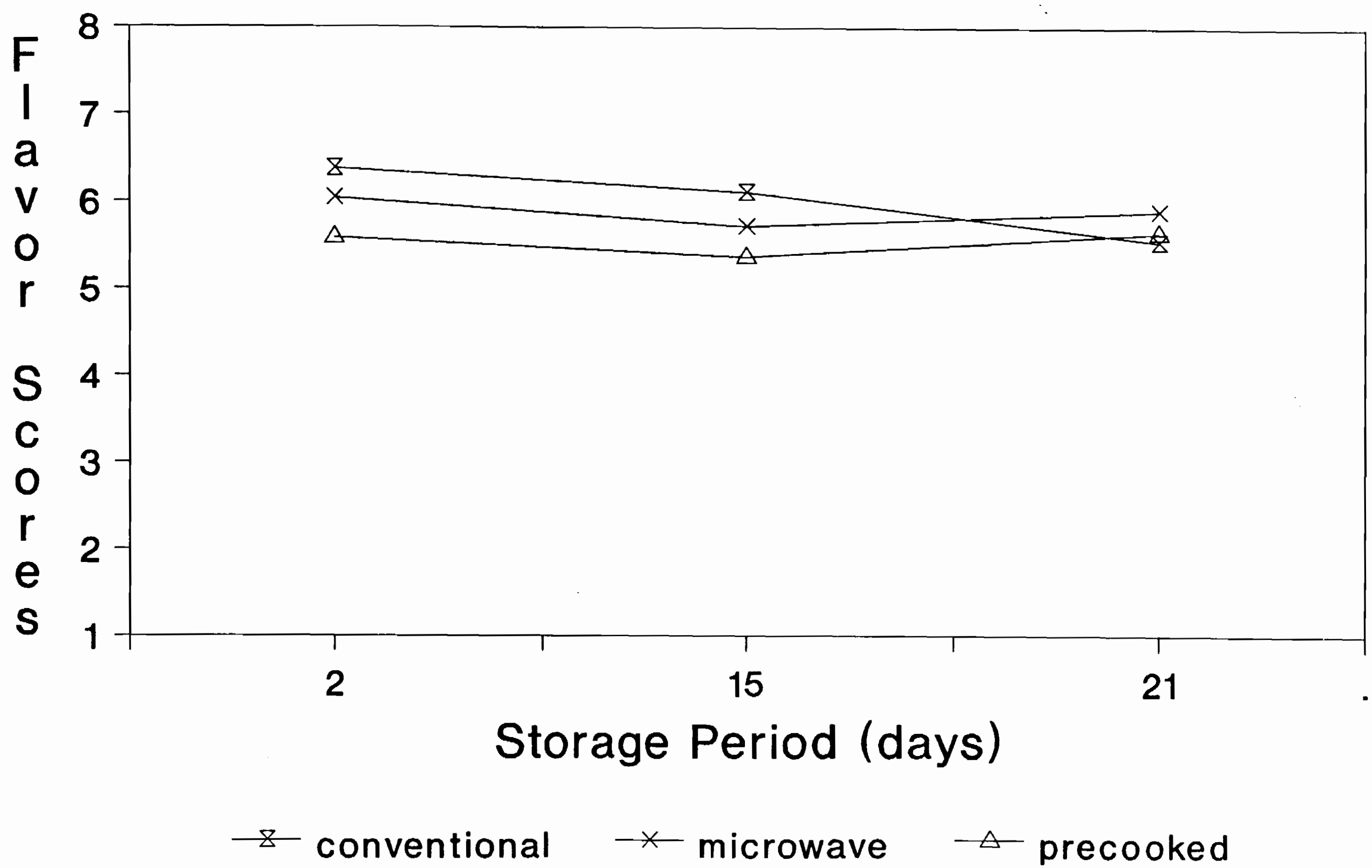


Figure 7. Cooking method * storage period interaction on overall flavor scores of whole muscle cuts

days. Flavor scores decreased during storage due to the increase in lipid oxidation during storage. Lipid oxidation causes rancid or off-flavors to develop (Tims and Watts, 1958; Sato and Hegarty, 1971).

Storage period did not affect (P>0.05) juiciness, texture, and overall flavor scores of restructured chops. The addition of salt to the formulation contributes to increased water binding capacity (Judge et al., 1989). Increased water binding capacity leads to less loss of moisture during storage, and this, in turn, contributes to the juiciness of the chops. These results are in agreement with Campbell and Mandigo who found that juiciness, texture, and flavor scores of restructured pork patties were unaffected by storage for up to six weeks. The effect of storage time on sensory traits of restructured pork chops is illustrated in Figure 5.

Large standard deviations were common among sensory traits due to blade tenderization, cooking method, and storage period. These values can be explained by the large number of scores obtained and the scores being rounded to the nearest whole number when samples were evaluated.

4.44 Relationship of Sensory Flavor Scores to TBA Values

There was a significant inverse correlation (r=-0.4483, P<0.01) between TBA values and sensory panel flavor scores for whole muscle samples. As TBA values increased, flavor scores decreased. The relationship due to cooking method is illustrated in Figure 8. A relationship between TBA and flavor and off-flavor in various meat products such as pork, beef, and chicken has been well documented (Penner and Bowers, 1973; Sato et al., 1973; Igene and Pearson, 1979; Igene et al., 1979; Johnston and Baldwin, 1980; MacDonald et al., 1980; Albrecht and Baldwin, 1982; Hsieh and Baldwin, 1984; Miller et al., 1985; Poste et al., 1986; Nolan et al., 1989; Boles and Parrish, 1990).

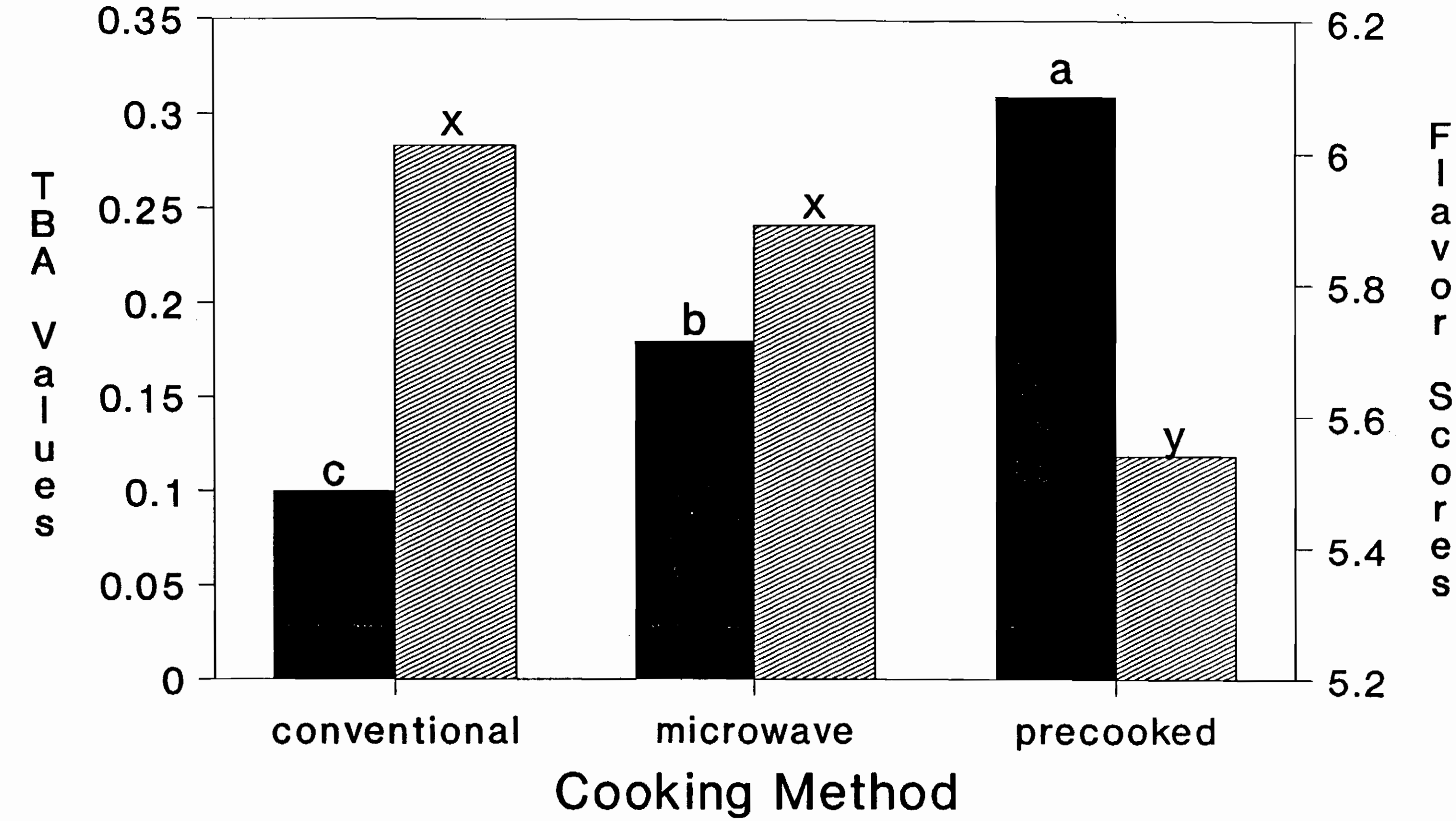


Figure 8. Correlation of TBA values and sensory scores of whole muscle cuts due to cooking method
[abc]bars with like letters are not different (P>0.05)
[xy] bars with like letters are not different (P>0.05)

CHAPTER V

SUMMARY AND CONCLUSIONS

Blade tenderization of whole muscle cuts affected only sensory panel texture scores resulting in treated samples receiving a slightly lower score. However, this value was in the moderately desirable to desirable range.

For whole muscle cuts, cooking method did not significantly affect fat content and percentage moisture. Precooked samples were similar to both conventional and microwave cooked samples in Warner-Bratzler shear force values. Precooked and microwave cooked samples were similar in sensory panel texture scores. Precooking resulted in higher TBA values and lower sensory panel juiciness and flavor scores than either conventional or microwave cooked samples. However, all sensory panel flavor scores were slightly desirable to moderately desirable.

Cooking method had no affect on fat content, percentage moisture, Warner-Bratzler shear force values, and sensory panel texture scores of restructured samples. Microwave cooked samples had the highest numerical TBA values which did not differ ($P>0.05$) from precooked samples. Precooked samples received lower sensory panel juiciness and flavor scores than both conventionally and microwave cooked samples. All sensory scores were, however, slightly desirable to desirable.

Storage period did not affect (P>0.05) a^* and b^* values, fat content in raw samples, and overall appearance of whole muscle cuts. Day 21 samples had less moisture and exhibited more oxidation. Day 21 chops did not differ from those stored for 15 days in L^* values, subjective color evaluation, Warner-Bratzler shear force values, and sensory panel juiciness, texture, and overall flavor scores. Storage for 15 days and 2 days was similar in percentage moisture, TBA values, L^* values, and Warner-Bratzler shear force values. Texture scores for day 2 and day 21 samples did not differ (P>0.05).

For restructured samples, storage time had no affect on moisture content, L^* a^* b^* values, color, overall appearance, Warner-Bratzler shear force values, and sensory panel juiciness, texture, and overall flavor scores. Day 21 chops had higher (P>0.05) fat content and TBA values than samples stored for 2 or 15 days. Day 15 chops had higher percentage fat and TBA values than those stored for 2 days, however, these differences were not significant (P>0.05).

The main conclusions that can be drawn from the results of this study are 1) blade tenderization has no advantages or disadvantages when performed on pork chops, 2) fat content and percentage moisture are not affected by cooking method, 3) precooked samples experience more lipid oxidation than conventionally cooked samples, 4) microwave cooked restructured chops are similar to conventionally cooked samples in moisture content and sensory traits of juiciness, texture, and overall flavor, 5) TBA values of whole muscle microwave cooked samples are more similar to precooked samples than conventionally cooked samples, 6) whole muscle MW cooked samples more closely resemble conventionally cooked samples in overall flavor and more similar to precooked samples in moisture content, Warner-Bratzler shear force values, and texture, 7) lipid oxidation increases with storage time.

More investigation is needed to explore new methods to control lipid oxidation in precooked pork as well as during storage. Furthermore, additional research should be conducted to improve the appearance of precooked pork cuts.

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APPENDIX A

Table 11 - Interaction[c] of cooking method and storage period on moisture content of pork longissimus muscle

	Cooking Method[d]			
	CO	MW	CMW	Standard error
Storage Period				
2 days	62.30[ax]	49.33[by]	61.85[ax]	1.52
15 days	60.68[ax]	54.95[ay]	57.89[abx]	1.52
21 days	54.55[bx]	52.70[abx]	57.18[bx]	1.52

[ab]Means with like superscripts within a column are not different (P>0.05)
[c]Interaction is significant (P<0.05)
[d]Cooking method: CO=conventional cookery, MW=microwave cookery, CMW=conventionally precooked/microwave reheated
[xy]Means with like superscripts within a row are not different (P>0.05)

Table 12 - Effects of blade tenderization on the objective tenderness measurement of pork longissimus muscle

	Blade Tenderization		
	blade tenderized	not tenderized	Standard error
Objective tenderness			
Peak force (kg)	2.92[a]	2.93[a]	0.06

[a]Means within the same row bearing like superscripts are not different (P>0.05)

Table 13 - Effects of blade tenderization on the sensory traits[c] of pork longissimus muscle

	Blade Tenderization			
	no tenderization		tenderization	
	Mean	SD	Mean	SD
Whole muscle				
juiciness	5.54[a]	1.25	5.37[a]	1.39
texture	6.34[a]	0.87	6.16[b]	1.15
overall flavor	5.81[a]	1.33	5.81[a]	1.24

[ab]Means within the same row bearing like superscripts are not different (P>0.05)
[c]Sensory traits: juiciness, texture, overall flavor: 1=very undesirable, 8=very desirable

Table 14 - Effects of cooking method on the sensory traits[d] of pork longissimus muscle and restructured pork chops

	Cooking Method[c]					
	CO		MW		CMW	
	Mean	SD	Mean	SD	Mean	SD
Whole muscle						
juiciness	6.32[a]	0.94	5.22[b]	1.21	4.82[c]	1.31
texture	6.56[a]	0.86	6.11[b]	1.12	6.07[b]	1.02
overall flavor	6.01[a]	1.27	5.89[a]	1.41	5.54[b]	1.10
Restructured muscle						
juiciness	7.01[a]	0.76	6.83[a]	0.81	6.30[b]	1.04
texture	5.64[a]	1.17	5.77[a]	1.10	5.82[a]	0.98
overall flavor	6.56[a]	0.79	6.63[a]	0.71	6.31[b]	0.94

[a-c]Means within the same row bearing like superscripts are not different (P>0.05)
[d]Sensory traits: juiciness, texture, overall flavor: 1=very undesirable, 8=very desirable
[c]Cooking method: CO=conventional oven cookery, MW=microwave oven cookery, CMW=conventionally precooked/microwave reheated

Table 15 - Effects of storage period on the sensory traits[c] of pork longissimus muscle and restructured pork chops

	Storage Period (days)					
	2		15		21	
	Mean	SD	Mean	SD	Mean	SD
Whole muscle						
juiciness	5.14[b]	1.46	5.66[a]	1.23	5.58[a]	1.20
texture	6.11[b]	1.21	6.35[a]	0.86	6.29[ab]	0.96
overall flavor	6.00[a]	1.19	5.74[b]	1.38	5.69[b]	1.26
Restructured muscle						
juiciness	6.67[a]	1.03	6.79[a]	0.88	6.68[a]	0.87
texture	5.68[a]	1.38	5.89[a]	0.86	5.69[a]	0.93
overall flavor	6.51[a]	0.84	6.49[a]	0.78	6.50[a]	0.87

[ab]Means within the same row bearing like superscripts are not different (P>0.05)
[c]Sensory traits: juiciness, texture, overall flavor: 1=very undesirable, 8=very desirable

VITA

Julie Ann Swenson was born on August 9, 1969 in Bristol, Pennsylvania. She graduated from Harmony Area High School in 1987 and received her Bachelor of Science degree, Magna Cum Laude, in Food and Nutrition Science from Indiana University of Pennsylvania in Indiana, Pennsylvania in 1991. She is a member of the Beta Sigma Chapter of Phi Mu National Fraternity for Women. In August, 1991 she began the Master of Science degree program in Food Science and Technology at Virginia Polytechnic Institute and State University. Julie has accepted a position in Technical Services with Ukrop's Supermarkets, Inc., in Richmond, Virginia.

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