AN EVALUATION OF DIFFERENT PACKAGING, PROCESSING AND DISPLAY SYSTEMS FOR FROZEN LAMB CHOPS

by

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B. S., University of Tennessee, 1972

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

Approved by:

Major Professor

ACKNOWLEDGEMENTS

The author wishes to extend his sincere appreciation to Dr. Harold J. Tuma, major professor, for his guidance in coordinating the frozen meat research projects. Special thanks are expressed to Dr. Don H. Kropf for his invaluable assistance and sincere interest throughout the author's graduate program.

Special appreciation is extended to Dr. Arthur D. Dayton for his assistance with the statistical analysis of data.

Acknowledgement is made to the American Sheep Producers Council for their financial support of this research.

The author is grateful to Joe Dunsmore for his efforts during the collection of data and to other graduate students for their assistance and friendship.

To my parents, Mr. and Mrs. Hugh D. Loveday, Sr., I am grateful for their encouragement and support throughout my academic endeavors.

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INTRODUCTION

As the meat industry moves toward centralized processing, distribution in frozen form seems a logical link between meat processors and retailers. Lamb marketing could be improved by centralized processing and distribution in frozen form to retail markets. In less populated areas, lamb tends to be a seasonal product and often is not available at all because of low and inconsistent demand. Frozen lamb cuts could be supplied throughout the year from a centralized cutting facility with better economic use made of all cuts; that is, each cut could be channeled to highest demand areas.

Frozen meat products offer greater efficiency and flexibility to meat fabrication, distribution and merchandizing. To date, frozen meat has been used primarily in supplying food service trade. Approximately 60% of the money spent for frozen meat has come from hotel, restaurant and institutional trade. With centralized cutting, labor, materials and facilities could be used with greater efficiency than in the numerous backrooms of retail markets. However, frozen meat has to overcome consumer and retailer skepticism to be successful (Tuma et al., 1973).

To sell frozen meat, the frozen product must be of equal or higher quality and acceptability as compared to fresh meat products. Preservation of the bright red oxymyoglobin pigment, which is commonly associated with fresh meat, is necessary so that frozen meat can gain its market share.

When frozen meat processing, packaging, handling and preservation methods are developed to insure color acceptability and palatability, frozen retail meat will give some marketing alternatives. Hopefully,

the lamb industry can expand its markets with frozen lamb.

The objective of this study was to evaluate color, microbiology, taste panel qualities, and display and cooking losses of displayed chops handled under different packaging, processing and display systems.

Chapter II

REVIEW OF LITERATURE

Effects of Oxygen Availability to Muscle

Oxygen Requirements of Muscle

Oxidation of myoglobin progressed more rapidly at low oxygen pressures (Brooks, 1938; George and Stratman, 1952). Brooks (1938) reported that the rate of methaemoglobin formation was maximized with oxygen pressures of about 4 mm Hg, and metmyoglobin formation was increased with low oxygen tensions. Rate of metmyoglobin formation for semitendinosus muscle was at a maximum with 6 $\pm$3 mm Hg at 0°C and 7.5 $\pm$3 mm Hg at 7°C (Ledward, 1970).

Effect of Vacuum Packaging

Several workers have shown the value of vacuum packaging for color retention of cured meats (Urbain and Ramsbottom, 1948; Ulrich, 1949; Brown and Schmucker, 1960; Alm, Erichsen and Molin, 1961). Greene (1969) stated that metmyoglobin formation and rancidity can be prevented by anaerobic packaging if adequate metmyoglobin reducing activity is present. One effect of fresh meat vacuum packaging, observed by many workers, has been rapid loss of bright redness by bloomed meat shortly after packaging but with subsequent reoxygenation when packages were opened (Landrock and Wallace, 1955; Rikert, Ball and Stier, 1957a; Rikert et al., 1957b; Rikert et al., 1957c; Pirko and Ayres, 1957; Dean and Ball, 1960b, Jaye, Kittaka and Ordal, 1962; Fellers et al., 1963; Pierson, Collins-Thompson and Ordal, 1970). Dean and Ball (1960b) noted that fresh meat vacuum packaged in cans, Mylar-Saran-polyethylene, polyethylene coated with

polyvinyl alcohol, polyethylene-cellophane-polyethylene, and Mylar-polyethylene will discolor, but a stable, durable red color was regenerated within two to four days. Fredholm (1963, as reported by Jeremiah, Smith and Carpenter, 1972c) observed that vacuum-packaged meats stored at 0 to 1°C for 14 days or more did not always regain bright red color upon exposure to air and were often grayish-brown on the surface. Hunt (1970) did not observe a regeneration of redness in frozen lamb chops that had been displayed for 42 days at -29°C and -21°C under 100 foot candle lighting. Pierson et al. (1970) reported that reduced myoglobin existed throughout the entire 15 day storage period in an anaerobic package whereas in aerobic packages a decline in oxymyoblobin and an increase in metmyoblobin was noted. After five days of storage at 3.3°C in an aerobic package, metmyoglobin completely covered the meat surface and by day seven the beef was completely unacceptable in terms of color, odor and flavor. No longissimus color differences as measured by percent reflectance at 630 nm were noted between fresh skin-tight packaged steaks and the conventional trayed-overwrap with PVC (Anonymous, 1973).

Gas permeability of packaging materials affects the product quality. Pirko and Ayres (1957) grouped various packaging films according to metmyoglobin formation and found that vacuum packaged fresh meat products did not discolor any faster than those packaged in films within a "least metmyoglobin formation group" of films. Hannan (1962) lists many packaging films and their oxygen permeabilities. Ground beef wrapped in Saran (low oxygen permeability) changed from oxymyoglobin to metmyoglobin to reduced myoglobin states, and then back to oxymyoglobin when the package was opened. Metmyoglobin was observed on hamburger after three to four days of storage at -1.1°C when packaged in 300 MSAD 80 cellophane (high

oxygen permeability) (Ordal, 1962). Color of beef steaks wrapped with PVC (high oxygen permeability) was marginal after four days storage at 0^{o}C (Dean and Ball, 1960a, Buck and Peters, 1970). Hunt (1970) noted that neither Saran (low oxygen permeability of 0.033 mm) nor Cryovac L-300 (high oxygen permeability of 4,000-5,000 cc/m^2/24 hours at 1 atm. at 23^{o}; 0.051 mm) preserved the fresh bloomed color of frozen lamb chops, but frozen lamb chops packaged in Cryovac L-300 had more acceptable visual and reflectance values than those in Saran packages. Landrock and Wallace (1955), Rikert et al. (1957a), and Dean and Ball (1960b) reported similar results. After one and 42 days of frozen display, lamb chops "vacuum packaged" in L-300 were more desirable visually than vacuum packaged lamb chops in Saran (Hunt, 1970). Landrock and Wallace (1955) suggested minimum oxygen permeability of a packaging material for fresh meat to be about 5000 ml O_2/sq. met./24 hrs./atm. at 75^{o}F.

Retail cuts from vacuum-packaged lamb wholesale racks and sirloins that had been stored for 14 days at 0^{o}C did not discolor at a faster rate than those from fresh wholesale cuts stored for 14 days at 0^{o}C. However, after three days of retail display at 0^{o}C, 82 foot candle lighting and in oxygen permeable film, chops from these vacuum packaged wholesale cuts were unacceptable due to discoloration and odor, but chops from fresh wholesale cuts had desirable color for six days of retail display (Jeremiah, Smith and Carpenter, 1972c). Color scores were higher for similarly handled "fresh" leg roasts than for roasts that had been vacuum packaged and stored for 11 days.

Effect of Freezing and Thawing on Color

More desirable visual color has been observed after freezing at lower

temperatures. Ramsbottom and Koonz (1941) found frozen meat to be darker when frozen at -12.2°C than at -34.4°C. Costello (1964) compared freezing temperatures of -18, -56.5, -101, -129, and -195.5°C and noted lighter colors for beef steaks frozen at lower temperatures. Hunt (1970) observed more desirable visual and reflectance scores for lamb chops frozen at -40°C than -26°C. Costello (1964) reported that freezing beef steaks at -195.5°C with liquid nitrogen produced lighter color, but steaks were darker when frozen at -17.8°C. According to Pearson and Miller (1950), the color of lean became progressively lighter as the rate of freezing increased from slow to rapid. Robertson (1950) reported freezing at -45.5°C to result in complete loss of surface redness.

Rikert et al. (1957b) noticed that frozen and thawed meat was lower in redness. Skin-tight packaged, frozen-thawed steaks had lower mean reflectance readings after five days of retail display than skin-tight packaged fresh or trayed-overwrap (Anonymous, 1973). Hunt (1970) found that visual scores were slightly higher for chops rapidly frozen at -40°C and thawed after 44 days of storage than chops frozen at -26°C and thawed after 44 days, but reflectance data did not support this. Costello (1964) reported no advantage in color after thawing of rapidly frozen beef semitendinosus steaks. According to Hunt (1970), chops packaged in oxygen impermeable film (Saran) had more desirable visual and reflectance scores when allowed to thaw and bloom after 44 days storage than those packaged in oxygen permeable L-300 film.

Brooks (1929) stated that freezing and thawing appeared to increase rate of metmyoglobin formation. Townsend and Bratzler (1958) reported that freezing and thawing had considerable effect on frozen meat color. They noted an alternate increase and decrease in the percent metmyoglobin

with alternate freezing (-28.9°C for 24 hrs.) and thawing (2.2°C for 24 hrs.) cycles of steaks packaged in Cryovac and aluminum foil. In contrast, Mangel (1951) reported that metmyoglobin did not increase with thawing and refreezing samples one to five times. Samples allowed to thaw more than one time developed off flavors and odors. Brown and Dolev (1963) used temperatures of 0, -5, -10, -15, and -18°C and found that oxidation rates increased sharply as the samples began to freeze at 10°C and continued to increase as the temperatures were lowered. They also noted that freezing and thawing (10°C) did not affect oxidation rates.

Microbiological Condition of Meat Cuts

Effects of Vacuum Packaging

Microbiological effects on fresh meat include 1) discoloration, 2) off odors, and 3) surface slime. A major effect of microorganisms affecting color was the accelearted rate of metmyoglobin formation which Butler, Bratzler and Mallman (1953) found to be concentrated during the logarithmic growth phase. Marriot et al. (1967) agreed that increased microbial growth enhanced meat discoloration. Butler et al. (1953) reported that shelf life of beef was extended by reducing initial microbial counts and by reducing storage temperatures. On the other hand, Cutaia and Ordal (1964) stated that when meat is stored under anaerobic environments, initial microbial counts had little or no effect upon subsequent metmyoglobin or reduced myoglobin formation.

Vacuum packaging of bacon (27-29 in. Hg) resulted in a superior product to non-vacuum packages based on the criteria of microbial counts, flavor and color (Brown and Schmucker, 1960). Pierson et al. (1970) reported that total microbial counts were always higher (10^{10}) and

increased more rapidly for aerobic packages than for anerobic packages (10^7). Evacuated polyvinylchloride (PVC) bags extended product life of poultry by inhibiting microbial growth (Wells, Spence and Stadelman, 1958). Halleck, Ball and Stier (1958) found total counts of vacuum packaged lamb to be considerably lower than for non-vacuum packaged lamb. Alm, Erichsen and Molin (1961) used the time to reach a count of 5×10^5 as a measure of product ability to keep fresh and observed that it took vacuum packaged (3 mm Hg) products longer to reach this viable count level than meats packaged at atmospheric pressure. A slight difference in favor of vacuum packaging was noted by Barlow and Kitchell (1966) between total counts, log 4.80 vs. log 4.98, for vacuum and air packaged lamb chops. Microbial growth reached a stationary phase at 10^8 microorganisms/gram after six days of storage with vacuum packaging compared to 21 days to reach a stationary phase and at a higher count (10^9) for air packages. However, vacuum packaging appeared to be non effective against total aerobic counts in fresh hamburger due to incorporation of air in the meat. Growth of anaerobes appeared earlier on vacuum packaged than air packaged hamburger (three days vs. six days, respectively) (Baran, Kraft and Walker, 1970; Beban, Kraft and Walker, 1970).

Ulrich (1949) reported that vacuum packaging can reduce growth of miccroorganisms but can not eliminate growth. According to one report (Anonymous, 1973), no significant differences in total counts were observed between fresh and vacuum packaged beef steaks displayed for five days at 0^oC. Linderholm (1960, as reported by Alm et al., 1961) found no difference between total plate counts of vacuum packed and non-vacuum packed sliced meats on the Swedish market.

Regan et al. (1971) reported that previous vacuum packaging of

wholesale loins adversely affected lamb loin chops. Those fresh loins had lower psychrotroph counts and 1½ more days of acceptable appearance in the display case. Maximum storage for vacuum packaged lamb loins was eight days if storage temperatures did not exceed 7°C (Regan et al., 1971; Jeremiah et al., 1972c). According to Jeremiah et al. (1971), spoilage appeared at a log count 4.6 and readily detectable spoilage at log count 5.6 for psychrotroph growth.

Several workers have noticed qualitative changes among the microflora found in vacuum packaging. Leistner (1956, 1957), as reported by Alm et al. (1961), believed these qualitative changes to be insignificant from the commercial standpoint. Lactobacillus species have been the dominant organisms found in vacuum packages (Allen and Foster, 1960; Alm et al., 1961; Pierson et al., 1970).

Beban et al. (1970) and Baran et al. (1970) agree that aerobic microbial counts will be greater with high oxygen permeable films than with oxygen impermeable films. They observed a stationary phase after six days of storage for the aerobic growth of organisms in vacuum packaged hamburger. Their explanation is that more oxygen was available for aerobic bacteria before the environment becomes anaerobic. Halleck et al. (1958), Shrimpton and Barnes (1960), Ordal (1962) and Ingram (1962) contend packaging materials with low oxygen permeability afford more protection against bacteria and thus longer shelf life. Ingram (1962) gives two possible explanations: 1) namely a lower oxygen content within the impermeable package, and 1) increased carbon dioxide content within the impermeable package (Shrimpton and Barnes, 1960).

Effect of Freezing and Thawing

Minimum temperature for psychrotrophic growth is about $-10^{o}C$. Temperatures below $-10^{o}C$ virtually eliminate metabolism and reproduction but enzyme systems of the cell may still function slowly, and cause food deterioration although microorganisms are not reproducing (Stokes, 1960). Birdseye (1929) reduced the bacterial count of haddock fillets from 7.7×10^{4} to 3.2×10^{4} per gram by "quick freezing." Counts for "frosted" hamburger were 89% lower than counts made on fresh hamburger (Geer, 1933). Freezing and storage decreased bacterial numbers on beans, snap beans, and corn (Hucker, Brooks and Emery, 1952). Cryogenic freezing and seven weeks storage of steaks lessened microorganism count by 37-83% depending on aging times of the steaks prior to cutting and freezing (Smith, 1970). On the other hand, beef loins that had been shell frozen by liquid nitrogen and stored for two and three days had higher total aerobic surface counts than fresh beef (Rey, Kraft and Rust, 1971).

Sulzbacher (1952) reported that freezing and thawing ground meat lengthened the logarithmic growth phase of psychrotrophic organisms and increased their generation time compared to unfrozen meat. Beef steaks packaged in skin tight transparent film, frozen in liquid nitrogen and allowed to thaw during display at $0^{o}C$ had lower mean total plate counts than fresh steaks skin tight packaged in the same transparent film or trayed-overwrapped with PVC (Anonymous, 1973).

Cooking and Packaging Loss

Effects of Vacuum Packaging

Buck and Peters (1970) reported weight losses for beef steaks packaged with PVC to vary from 1.3% to 5.0% depending upon the type of

tray and storage time. Vacuum packaging of lamb wholesale cuts was successful in reducing weight loss during storage and retail display (Jeremiah et al., 1972b). Ball, Clauss and Stier (1957) recorded a net packaging loss of 1.2% for meat vacuum packaged in cellulose acetate-pliofilm laminate (pliofilm on inside), 1.7% for meat packed in cans, 2.0% for meat vacuum packaged in cellophane-polyethylene laminate (polyethylene on inside), 2.2% for meat vacuum packaged in cellophane-pliofilm laminate (pliofilm on inside), 3.8% for meat vacuum packaged in MSAT 86 cellophane (both sides coated), 9.8% for meat vacuum packaged in MSAT 80 cellophane (coated on inside) and 26% for unpackaged meat products. No significant percent cooking loss differences were found between skin tight packaged beef steaks and steaks trayed-overwrapped with PVC (Anonymous, 1973).

Effect of Freezing and Thawing

Awad (1968) found thaw drip loss from bovine muscle stored at $4^{o}C$ to increase with storage from 7.3 ml/100 gram muscle for unfrozen to 24.0 ml/100 gram muscle for 8 weeks of frozen storage. With lower freezing temperature, percent drip loss appears to be lowered (Ramsbottom and Koonz, 1939; Pearson and Miller, 1950; Hunt, 1970). However, Costello (1964) froze steaks in liquid nitrogen at temperatures ranging from -17.8 to $-195.5^{o}C$ and found that freezing temperature did not affect drip loss or cooking loss. Brady, Frei and Hickman (1942) also observed less cooking loss with rapid freezing of beef, pork and lamb regardless if cooked from frozen or thawed state. However, most reports indicate that with faster freezing of meat, percent cooking loss or total weight loss is increased. Bannister et al. (1971) found that pork chops frozen in liquid nitrogen

had significantly more cooking loss than chops frozen in three types of home freezers. A 3 to 5% increase in percent cooking loss was reported by Berry et al. (1971) by freezing pork chops at -196°C compared to -18°C. A slight increase in cooking time as well as more cooking loss resulted when Lind, Harrison and Kropf (1971) reduced the freezing temperature.

Love and Karsti (1958) found that cell damage alternatively increased or decreased with reduced freezing temperatures which may result in more or less cooking loss depending on the extent of cell damage.

Smith et al. (1968), Bannister et al. (1971) and Berry et al. (1971) observed that frozen meat has a greater cooking loss. Beef steaks that were frozen and then allowed to thaw while being displayed in a retail case had approximately 2% greater cooking loss than beef steaks displayed fresh (Anonymous, 1973).

Lind et al. (1971) reported higher weight loss by cooking pork chops from the frozen state rather than allowing them to thaw prior to cooking. In contrast, Brady et al. (1942) observed that steaks from beef, pork and lamb cooked from the frozen condition had lower cooking losses regardless of freezing method.

Tempering Effects

Many reports have concluded that lower storage temperatures will improve shelf life and product acceptability of prepackaged meat (Ramsbottom and Koonz, 1941; Butler et al., 1953; Rikert et al., 1957b; Jaye et al., 1962; Fellers et al., 1963; Cutaia and Ordal, 1964). Brooks (1938) found that oxidation of meat was very slow at -10°C. Metmyoglobin formation was slower at -12°C than -18°C or -24°C (Mangel, 1951). However, other reports indicate detrimental changes that occur near freezing

temperatures of meat and other foods. Fennema (1971) reported that oxidation and protein insolubilization reactions which can affect food quality are accelerated in the temperature range of -1 to -15°C. Satterlee and Zachariah (1972) noted increased autoxidation at temperatures below freezing (-12°C and -19°C) for beef, pork and lamb. Brown and Dolev (1961) showed that oxidation rates increased sharply as beef oxymyoglobin solutions began to solidify in freezing.

Color Measurement by Reflectance Spectrophotometry

Broumand, Ball and Stier (1958) reported use of transmission spectrophotometry to determine myoglobin chemical state from meat surface extracts. Dean and Ball (1960a) developed a method, based upon results of Broumand *et al.* (1958) using absorbancy ratios, to quantitatively measure relative amounts of reduced myoglobin, oxymyoglobin and metmyoglobin by determining K/S values at wavelengths of 507/573 and 473/597 from reflectance data [K/S value is the ratio of absorption coefficient (K) to the scattering coefficient (S) per unit of sample thickness]. A curve relating absorbancy ratios to the percent of each myoglobin form can be constructed for each ratio (Broumand *et al.*, 1958 and Dean and Ball, 1960a). Using the above method, two myoglobin forms can be determined and the third form can be calculated by difference (Snyder, 1968).

Stewart, Zipser and Watts (1965) reported that a linear relationship, rather than a curvilinear one used by Broumand *et al.* (1958) and Dean and Ball (1960a), should exist between various absorbancy ratios and myoglobin forms with that at 525 nm used as the denominator since 525 nm is an isobestic point for all three major myoglobin chemical forms. Stewart and co-workers (1965) proposed to measure myoglobin state by using a ratio

of K/S at 572 to that at 525 nm which would differentiate 100% metmyoglobin from 100% reduced myoglobin plus oxymyoglobin. A ratio of reflectance at 474 nm/525 nm would separate 100% reduced myoglobin from 100% oxymyoglobin plus methmyglobin. Snyder and Armstrong (1967) confirmed the linear relationship of Stewart et al. (1965) by using purified oxymyoglobin and metmyoglobin in non fat dried milk at various proportions of their combined total and adjusting reflectance to equal 1.0 at 525 nm measured on the absorbancy scale (Ra), as suggested earlier by Snyder (1965).

Stewart et al. (1965) also revealed that reflectance ratios were not the same for absorbancy and transmission.

Direct reflectance spectra at 400 to 425 nm and 500 to 600 nm allow identification of hematin compounds and their derivatives and involve no extraction, a likely source of error in other methods (Tappel and Maier, 1957; Snyder, 1968 and Franke and Solberg, 1971). Using tuna fish samples, Naughton, Zeithin and Frodyma (1958) reported reflected light measured on an absorbance scale to be directly related to proportions of reduced myoglobin, oxymyoglobin, and metmyoglobin.

Green, Hsin and Zipser (1971) found percent metmyoglobin to be an objective measurement of raw beef color, but total pigment level was not. Lane and Bratzler (1962) concluded that spectrophotometry was useful in estimating percent metmyoglobin in meat extract solutions that have been frozen.

Snyder (1965) suggested concentrating on wavelengths in the red spectrum to quantitate proportion of metmyoglobin. To determine desirable meat color, Hansen and Sereika (1969) found reflectance ratios of 582/525 (< 1.12) and 630/525 ($< .55$), used in combination with each other to be acceptable standards for desirably colored frozen beef muscle. Wavelengths

of 540, 560, 575, and 630 nm were used by Mangel (1951) to estimate metmyoglobin formation. Several workers reported that reflectance at wavelengths in the range of 600 to 650 nm have been useful in estimating percent metmyoglobin. Franke and Solberg (1971) found reflectance at 632 nm to be inversely related to amount of metmyoglobin on the meat surface. Ginger, Wilson and Schweigert (1954) and Pirko and Ayres (1957) agreed that a lesser reflectance value at 635 nm indicated more metmyoglobin. Decreased absorption at 555 nm and increased absorption at 635 nm were criteria used by Ginger et al. (1954) to detect pigment change to metmyoglobin. Snyder (1965) observed more change at 630 nm than at 571 nm with fresh beef discoloration due to "greater penetrating power and less light scattering at the longer wavelength." According to Allen et al. (1969) unadjusted reflectance readings at 525, 538, 568 and 571 nm were unable to detect fresh beef color deterioration; however, a decrease in reflectance values at 600, 610, 620 and 630 nm were observed as color degenerated. Santamaria (1970) agreed that reflectance values at shorter wavelengths than 600 nm tended to be insensitive to color deterioration in frozen beef and those at wavelengths ranging from 600 to 650 nm were more useful in predicting metmyoglobin content. Allen et al. (1969) also stated that a ratio of 474 nm/525 nm increased as color acceptability decreased and was more useful in following color changes than a 571 nm/525 nm reflectance ratio.

Bowen (1949) found that absorption of metmyoglobin from horse heart myoglobin at 495, 525 and 628 nm was not affected by pH.

Reflectance at wavelengths of 625 and 655 nm have been reported as being more closely related to visual scores than those at 415, 445, 475, 505, 535, 565, 595 and 685 nm (Jeremiah, Carpenter and Smith, 1972a).

Ockerman and Cahill (1969) observed reflectance to be a rapid and objective measurement of muscle color. They noted a correlation coefficient of 0.85 for visual scores and percent reflectance at 685 nm.

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Chapter III

AN EVALUATION OF PACKAGING SYSTEMS FOR FRESH, FROZEN-THAWED AND FROZEN LAMB CHOPS

As the meat industry moves toward centralized processing, distribution in frozen form seems to be a logical link between meat processors and retailers. Frozen meat products offer greater efficiency and flexibility to meat fabrication, distribution and merchandizing. In less populated areas, lamb tends to be a seasonal product and often times is not available at all because of low and inconsistent demand. Frozen lamb cuts could be supplied throughout the year from a central cutting facility with better economic use made of all cuts; that is, each cut could be channeled to highest demand areas.

To sell frozen meat, the product must be of equal or higher quality and acceptability as compared to fresh meat products. Maintenance of the bright red oxymyoglobin pigment, which is commonly associated with fresh meat, is necessary so that frozen meat can gain its market share.

When frozen meat processing, packaging, handling and preservation methods are developed to insure color acceptability and palatability, frozen retail meat will give some marketing alternatives. Hopefully, the lamb industry can expand their market with frozen lamb. The objective of this study was to evaluate color, microbiology, taste panel qualities, display weight loss and cooking loss of displayed chops handled under different packaging and processing systems.

Experimental Procedure

Sample Selection, Preparation and Display

Choice lamb loins were purchased from a commercial packer and Kansas

State University Meats Laboratory. Loin chops taken two to three days post-mortem were cut 2.54 cm thick. For six replications, chops were fabricated on the band saw and for six other replications chops were cut from loins that had been tempered to an internal temperature of -2.2°C and cleaved with the Bettcher power cleaver. After the chops had bloomed for at least 15 minutes, six chops (two replications) were randomly assigned to each of the following seven temperature-film treatments:

1) Fresh, overwrap in tray with polyvinylchloride (PVC)
2) Fresh, skin tight Iolon
3) Frozen-thawed, skin tight Iolon
4) Fresh, skin tight 241
5) Frozen-thawed, skin tight 241
6) Frozen, skin tight Iolon
7) Frozen, skin tight 241

Treatments two through seven were packaged with DuPont Bivac system using a vacuum of 27 in. Hg. Iolon film (3 ml) has medium oxygen permeability, but 241 (2 ml) has greater oxygen permeability. PVC (1 ml) was of high oxygen permeability. After packaging, treatments three, five, six and seven were crust frozen in liquid nitrogen vapor by use of a liquid nitrogen freezing simulator with a step-wise freezing cycle beginning at 0°C and continuing to -150°C (about 5 minutes total freezing time to prevent bleaching). After freezing, treatments three, five, six, and seven were stored for seven days in the dark at -31.7°C. Treatments one through five were displayed at 0 to 1°C while treatments six and seven were displayed at -31.7°C (temperature near top surface of displayed cuts). All treatments were displayed for five days under Delux Warm White lights at 100 foot candles with display lights turned off for 12 hours daily.

Color, microbial growth, display and cooking loss, and sensory qualities were evaluated after one, three and five days of display.

Color Measurements

Care was taken to expose the same chop surface to display lighting throughout the study. Longissimus muscles of day five chops were color scored both visually and objectively after one, three and five days of display. Objective color was measured with a Bausch and Lomb 600 Spectrophotometer with reflectance attachment calibrated for 100% reflectance with $MgCO_3$. Reflectance spectra were scanned from 400 nm to 700 nm at a recording speed of 250 nm/minute. Reflectance readings were determined to the nearest 0.1% at a wavelength of 630 nm. Research by Ginger et al. (1954), Pirko and Ayres (1957), Snyder (1965), Allen et al. (1969), Santameria (1970) and Franke and Solberg (1971) have shown that wavelengths near 630 nm are useful in detecting meat discoloration. Visual color score consisted of independent evaluations by two judges who scored the chops under the display lighting system to the nearest 0.5 point using a scale of 1 = very bright, 2 = bright, 3 = slightly dark, 4 = dark and 5 = extremely dark for visual appraisal of the longissimus (Anonymous, 1973).

Microbiological

Total aerobic counts were determined using standard methods agar (Hausler, 1972) with plates incubated for four days at 25°C. Packages were aseptically opened using a flamed scalpel. A sterile, aluminum foil template was placed on the loineye muscle and an area of 10 cm^2 was swabbed using a moist, sterile cotton swab. The swab was then placed in 10 ml of sterile water making a dilution factor of 1:10 from which further dilutions were made. Appropriate dilutions were based on previous counts

and trends; therefore, dilutions varied from day to day and week to week. Agar, dilution blanks and swab bottles were autoclaved at 121°C for 15 minutes at 15 p.s.i. Pipettes were sterilized at 170°C in a forced air oven for one hour (Hausler, 1972). Sterile, plastic disposable petri dishes were used. Colonies were counted with a Quebec colony counter.

Display and Cooking Loss

Display weight loss was expressed as a percent of the chop weight prior to packaging. After package removal, chops were weighed, placed on a broiler pan and placed in a gas fired rotary oven that was pre-heated to 176.5°C, with chops cooked to an internal temperature of 71°C. After removal from the oven, chops were weighed so total cooking loss could be calculated.

Taste Panel

Each member of a six person taste panel received a 1.27 cm longissimus core of each sample. Flavor, juiciness, tenderness and over-all acceptability were evaluated by a hedonic scale ranging from one to nine, with nine being extremely desirable. A score of five or higher is considered to be acceptable.

Statistical Procedure

Analysis of variance and least significant differences (LSD) were used to determine treatment differences.

Results and Discussion

Color

Color is an important product appearance factor in marketing of meat. Visual and reflectance data (Table 1) suggest no treatment differences

Table 1. Mean % Reflectance at 630 nm and Visual Color Scores for Fresh, Frozen-Thawed and Frozen Lamb Chops

Treatment	Display Time					
	Day 1		Day 3		Day 5	
	% Reflectance	Visual[a]	% Reflectance	Visual[a]	% Reflectance	Visual[a]
Tray-Overwrap	21.1	2.8	19.8[c]	3.5[b,c]	20.6[c]	4.1[b,c]
Iolon Fresh	22.7	3.0	20.8[c]	3.6[b,c]	19.8[c]	4.1[b,c]
Iolon Frozen-Thawed	17.2	3.4	18.6[c]	3.9[c]	17.8[c]	4.4[c]
241 Fresh	24.3	2.7	21.0[c]	3.2[b]	20.1[c]	3.8[b]
241 Frozen-Thawed	18.4	2.9	18.6[c]	3.9[c]	18.1[c]	4.4[c]
Iolon Frozen	30.9	3.0	33.0[b]	3.4[b]	28.4[b]	3.7[b]
241 Frozen	33.9	2.9	31.3[b]	3.3[b]	27.7[b]	3.7[b]

[a]Visual color: 1 = very bright, 3.5 = marginally acceptable, 5 = extremely dark

[b,c]Means within same column bearing same or no superscript letters do not differ significantly ($P < .05$).

after day one of display. After three or five days of display, frozen chops in both Iolon and 241 had a significantly ($P < .05$) higher % reflectance at 630 nm suggesting a brighter red color. Visual scores showed a significant ($P < .05$) color advantage for frozen chops and for fresh chops packaged in 241 film over treatments involving freezing and thawing. The higher reflectance may partly be the result of slight bleaching or of greater reflective properties of frozen chops. Robertson (1950), Pearson and Miller (1950) and Costello (1964) also found lighter surface color for frozen meat. The less desirable color of thawed meat agrees with the data of Brooks (1929), Rikert et al. (1957b), Townsend and Bratzler (1958) and Hunt (1970).

Frozen-thawed chops in Iolon were nearing unacceptable color after day one. Fresh chops packaged in film 241 tended to have more desirable color scores than those in Iolon.

Chops fabricated by the band saw were significantly ($P < .05$) more desirable in mean visual color score than tempered and cleaved chops after one or three days of display (Table 2). However, after five days display no differences were evident. Reflectance values show no significant ($P < .05$) difference between preparation methods. A possible explanation for the difference between the sawed and tempered and cleaved chops is the oxidation of myoglobin sharply increased as meat began to solidify. This possiblity is supported by work of Brown and Dolev (1963) and Satterlee and Zachariah (1972).

Microbiological

Rapid freezing and frozen storage significantly ($P < .05$) lowered microbial levels after one or five days (Table 3). Smith (1970) depressed microorganism growth by 37 to 83% by cryogenic freezing and seven weeks

Table 2. Effect of Preparation Method on Mean % Reflectance at 630 nm and Visual Scores for Fresh, Frozen-Thawed and Frozen Lamb Chops

Preparation Method	Display Time					
	Day 1		Day 3		Day 5	
	% Reflectance	Visual[a]	% Reflectance	Visual[a]	% Reflectance	Visual[a]
Tempered-Cleaved	24.2	3.2[c]	23.3	3.8[c]	22.1	4.1
Sawed	24.0	2.7[b]	23.3	3.2[b]	21.b	3.9

[a]Visual color: 1 = very bright, 3.5 marginally acceptable, 5 = extremely dark

[b,c]Means within same column bearing same or no superscript letters do not differ significantly ($P < .05$).

Table 3. Effect of Film and Fresh, Frozen-Thawed and Frozen Lamb Chop Treatment on Mean Plate Counts (Log counts/10 cm^2)

	Display Time		
Treatment	Day 1	Day 3	Day 5
Tray-Overwrap	$3.75^{b,c}$	3.07	4.38^{b}
Iolon Fresh	$3.38^{b,c}$	3.54	$3.61^{a,b}$
Iolon Frozen-Thawed	$3.01^{a,b}$	2.76	$3.46^{a,b}$
241 Fresh	3.76^{c}	3.24	4.00^{b}
241 Frozen-Thawed	$3.11^{a,b}$	2.94	$3.38^{a,b}$
Iolon Frozen	2.73^{a}	2.61	2.70^{a}
241 Frozen	2.62^{a}	2.93	2.70^{a}

^{a,b,c}Means within same column bearing same or no superscript letters do not differ significantly ($P < .05$).

frozen storage, and Birdseye (1929) reduced microbial counts on haddock fillets by freezing. Freezing decreased microbial numbers on vegetables (Geer, 1933; Hucker et al., 1952).

Frozen-thawed treatments had lower log counts than fresh treatments which agrees with Sulzbacher (1952) and Anonymous (1973). Microbial levels tended to be lower on chops displayed three days than on those displayed either one or five days, an unexpected result.

Display and Cooking Loss

Although a significant ($P < .05$) difference was found on day one for display weight loss, no further consistent trends among the treatments for packaging loss were detected (Table 4).

Cooking loss for the tray-overwrap was significantly ($P < .05$) less than frozen-thawed or frozen treatments after day three of display (Table 4). However, no treatment differences were found for cuts displayed one or five days. Frozen-thawed chops had 1.5 to 3.0% more cooking loss over the five day display period than fresh treatments. After three or five days, the frozen treatments tended to have the most cooking loss. Bannister et al. (1971) and Berry et al. (1971) observed increased cooking losses with rapidly frozen pork chops as compared to slower, conventional freezing methods, and Lind et al. (1971) found greater cooking losses for lamb chops as the freezing temperatures decreased. In contrast, Ramsbottom and Koonz (1939), Brady et al. (1942), Pearson and Miller (1950), Costello (1964) and Hunt (1970) found that rapid freezing did not increase drip or cooking loss. Perhaps this is dependant on specific temperatures used (Love and Karsti, 1958). Cooking losses tended to decrease with storage (Pearson and Miller, 1950 and Berry et al., 1971).

Table 4. Effect of Film and Fresh, Frozen-Thawed and Frozen Lamb Chops Treatment on Mean Display Loss and Cooking Loss

Treatment	Display Time					
	Day 1		Day 3		Day 5	
	% Display Loss	% Cooking Loss	% Display Loss	% Cooking Loss	% Display Loss	% Cooking Loss
Tray-Overwrap	0.00[a]	19.20	0.60	16.36[a]	3.77	12.64
Iolon Fresh	1.48[a,b]	18.94	2.21	17.74[a,b]	3.13	14.05
Iolon Frozen-Thawed	4.39[b]	20.70	3.08	20.62[b]	3.96	15.52
241 Fresh	0.00[a]	18.84	1.59	17.75[a,b]	0.00	15.53
241 Frozen-Thawed	1.08[a,b]	21.90	2.24	20.76[b]	1.53	16.03
Iolon Frozen	3.33[b]	18.84	2.26	23.09[b]	1.79	16.94
241 Frozen	1.01[a,b]	20.74	1.16	22.35[b]	1.53	17.42

[a,b]Means within same column bearing same or no superscript letters do not differ significantly ($P < .05$).

Taste Panel

After three days of display, juiciness and over-all acceptability were significantly ($P < .05$) lower, but acceptable, for frozen chops packaged in either Iolon or 241 film. Day three frozen chops had the greatest cooking loss which may partly account for lower juiciness scores. Lower over-all acceptability scores for frozen chops at day three likely resulted from the lower juiciness scores. Although color of the chops was unacceptable by day five, mean taste panel scores on day five were acceptable (Appendix Table A).

Summary

Color, display weight loss, cooking loss, microbiology and taste panel qualities were evaluated for fresh, frozen-thawed and frozen lamb chops packaged in three types of film. Twelve replications of three chops per treatment utilizing 252 chops were made; six cut by the band saw and six other replications from tempered and cleaved loin chops.

Frozen chops had brighter red color as indicated by visual and reflectance data. However, the increased % reflectance at 630 nm may result partly from slight bleaching on the meat surface and higher reflectance of frozen muscle. Frozen-thawed chops had the least desirable color as indicated by lower % reflectance at 630 nm and by visual scores. All chops had unacceptable color after five days of display. Slightly better color scores for film 241 than for Iolon film may have been related to its higher oxygen permeability.

Visual scores suggest chops prepared by the power meat saw were significantly ($P < .05$) more desirable in color than tempered and cleaved chops but this difference was not confirmed by the reflectance readings.

Rapid freezing and frozen storage significantly ($P < .05$) lowered microbial level compared to other display treatments after one or five days of display.

Frozen-thawed chops produced the greatest cooking loss after one day of display. After three or five display days, frozen chops had more cooking loss than other treatments. Cooking loss tended to decrease with storage.

No trends among treatments were detected for display losses.

Taste panel scores for flavor, juiciness, tenderness and over-all acceptability were acceptable for all chops even after five days of display, despite the appearance of unacceptable color.

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Chapter IV

AN EVALUATION OF DISPLAY SYSTEMS FOR FROZEN LAMB CHOPS PACKAGED IN SKIN TIGHT TRANSPARENT FILM

Lamb marketing could be improved by centralized processing and distribution in frozen form to retail markets. In less populated areas, lamb tends to be a seasonal product or often is not available because of low and inconsistent demands. Frozen lamb chops and leg roasts from a centralized cutting facility could be supplied throughout the year with better economic use made of all cuts; i.e., each cut could be channeled to highest demand areas. As an alternative, retailers could purchase frozen lamb rather than intact carcasses since there is the problem of disposing of less preferred cuts and waste trim.

To date, frozen meat has been used primarily in supplying food service trade. Approximately 60% of the money spent for frozen meat has come from hotel, restaurant and institutional trade. With centralized cutting, labor and materials and facilities could be used with greater efficiency than in the numerous backrooms of retail markets. However, frozen meat has to overcome consumer and retailer skepticism to be successful (Tuma et al., 1973).

As preservation methods improve, greater flexibility can be incorporated into meat marketing systems. The objective of this study was to evaluate the effect of different packaging and freezer display systems for frozen lamb chops on color, microbiology, taste panel evaluations, display and cooking loss.

Experimental Procedure

Sample Selection, Preparation and Display

Choice lamb loins were purchased from a commercial packer and from the Kansas State University Meats Laboratory. Each packaging day, one loin was designated for day five chops to eliminate loin difference for color appraisal. Color was evaluated on these chops after one, three and five days of display and were used for day five cooking, taste panel and microbial evaluations. Loin chops cut 2.54 cm thick by band saw were taken two to three days post-mortem. The design involved combinations of two film types, three display freezers and two freezing-packaging sequences (Table 5).

Table 5. Experimental Treatments

Treatment	Film Type	Freezer Display	Display Temperature (C^{o})	Freezing-Packaging Sequence
1	Iolon	Spot	-23.9	Frozen-Packaged
2	241	Spot	-23.9	Frozen-Packaged
3	Iolon	Upright	-31.7	Frozen-Packaged
4	241	Upright	-31.7	Frozen-Packaged
5	Iolon	Open Top	-31.7	Frozen-Packaged
6	241	Open Top	-31.7	Frozen-Packaged
7	Iolon	Open Top	-31.7	Packaged-Frozen
8	241	Open Top	-31.7	Packaged-Frozen

Prior to packaging by DuPont Bivac system, treatments one through six involved freezing in liquid nitrogen vapor by use of a liquid nitrogen

freezing simulator with step-wise temperature cycle beginning a 0°C and ending at -150°C (about five minutes total freezing time to prevent bleaching) and then warming on the surface with a hot air blower to brighten surface color. Treatments seven and eight were packaged before a similar crust freezing.

Microbiological

Microbial procedures were the same as in Chapter III, but with addition of plating for total psychrotrophic counts. Psychrotrophs were cultured on standard methods agar and incubated at 7°C for ten days (Hausler, 1972).

Procedures for color, display loss, cooking loss and taste panel determinations are the same as in Chapter III.

Results and Discussion

Comparison of results of display freezers should be confined to those using the frozen-packaged sequence and those of the freezing-packaging sequence should consider only the open top display freezer.

Color

Lamb chops displayed in the upright case had a more desirable color than chops displayed in either the spot or open top case as indicated by both higher mean % reflectance at 630 nm and by a trend toward more desirable visual scores (Table 6). Chops displayed in the upright case were significantly ($P < .05$) more desirable than chops displayed in the open top case (frozen-packaged). Since chops were displayed flat and the light source was located in the front of the upright case, less light absorption by the meat or greater reflectance of the light by the films

Table 6. Effect of Display Freezer and Freeze-Packaging Sequence on Mean % Reflectance at 630 nm and Visual Scores for Frozen Lamb Chops[a]

Display Freezer	Spot	Upright	Open Top	Open Top
Sequence	Fz-Pkg	Fz-Pkg	Fz-Pkg	Pkg-Fz
% Reflectance	28.2[c,d]	30.6[c]	27.2[d]	29.9[c,d]
Visual[b]	2.8	2.5	2.8	3.2

[a]Means averaged for display days one, three and five.

[b]Visual color: 1 = very bright, 3.5 = marginally acceptable, 5 = extremely dark.

[c,d]Means within same row bearing same or no superscript letters do not differ significantly ($P < .05$).

may result since light waves contact the muscle surface less directly (more obliquely) and may account for the better color readings.

Visual color scores indicated an interaction between display freezer and film (Table 7). For frozen-packaged chops displayed in the open top case, use of 241 film resulted in brighter average visual score and a trend toward higher reflectance than use of Iolon film. For chops packaged-frozen, a more desirable visual score was noted for those chops packaged in Iolon, but this was not substantiated by a higher reflectance. This was unexpected if the oxygen permeability properties of the 241 film are superior to Iolon at -31.7°C (display temperature) as they are at 22°C (O_2 permeability determination temperature). Generally, visual scores suggest that freezing and warming the meat surface prior to packaging produced greater color acceptability than packaging before freezing. It appears that film 241 is best suited for frozen display if the chops are frozen and surface warmed prior to packaging. On the other hand, freezing packaging sequence did not affect visual score of chops packaged in Iolon.

Average reflectance at 630 nm for chops in 241 was significantly ($P < .05$) more desirable than for chops in Iolon film (Table 7). Although visual scores tend to support this, these differences are not significant.

Microbiological

No significant ($P < .05$) differences between films or among display freezer, freeze-package sequence were detected for either plate counts or total psychrotroph counts.

Plate counts tended to decrease from day one to day three of display and to increase from day three to day five of display. By day five, chops packaged in Iolon had equaled or exceeded day one counts while plate counts

Table 7. Mean % Reflectance at 630 nm and Visual Scores for Frozen Lamb Chops Packaged with Iolon and 241 Films and Displayed in Spot, Upright and Open Top Cases[a]

	Iolon Film		241 Film	
Treatments	% Reflectance	Visual[b]	% Reflectance	Visual[b]
Spot (Fz-Pkg)	25.8	2.8[c,d]	30.6	2.7[c,d]
Upright (Fz-Pkg)	28.0	2.6[c]	33.0	2.5[c]
Open Top (Fz-Pkg)	24.4	3.0[d]	30.0	2.7[c]
Open Top (Pkg-Fz)	27.7	3.1[d]	32.0	3.3[e]
All Treatments	26.5[g]	2.9	31.4[f]	2.8

[a]Means averaged for display days one, three and five.

[b]Visual color: 1 = very bright, 3.5 = marginally acceptable, 5 = extremely dark.

[c,d,e]Means for both visual color columns bearing same or no superscript letters do not differ significantly ($P < .05$)

[f,g]Film means bearing different superscripts differ significantly ($P < .05$).

Table 8. Effect of Film, Freezing-Packaging Sequence, Display Freezer and Display Time on Mean Log Plate Counts[a]

Freezer Treatments	Log TPC (10 cm^2)					
	Day 1		Day 3		Day 5	
(Freezing-Packaging Sequence)	Iolon	241	Iolon	241	Iolon	241
Spot (Fz-Pkg)	2.91	3.38	1.89	2.29	2.85	2.62
Upright (Fz-Pkg)	2.67	3.39	1.68	1.94	2.98	2.61
Open Top (Fz-Pkg)	3.10	3.47	1.43	2.61	3.28	2.85
Open Top (Pkg-Fz)	2.75	3.34	1.93	2.36	3.10	3.11
Film Means	2.86	3.39	1.73	2.30	3.05	2.80

[a]No significant differences ($P < .05$).

for 241 packaged chops increased but did not return to the day one level (Table 8). Psychrotroph counts for chops packaged in Iolon followed the same trend over the display period noted for plate counts but did not attain day one microbial counts after five days of display. Film 241 packaged chops showed a decline in total psychrotroph counts from day one to day five of display (Table 9).

Display and Cooking Loss

Film type, freezing-packaging sequence or display freezer did not significantly ($P < .05$) affect the percent display loss (Table 10).

On day one of display, chops packaged in 241 film and displayed in either the spot or upright display freezer had significantly ($P < .05$) less cooking loss than Iolon packaged chops displayed in the spot or upright case (Table 11). No difference due to display freezer, freezing-packaging sequence or films was detected after three and five days of display.

Cooking loss for Iolon packaged chops was significantly ($P < .05$) higher than for 241 packaged chops after one day of display, but these differences were not evident after three and five days of display.

For frozen chops, cooking losses tended to increase with storage, regardless of treatment, which is contrary to the data of Pearson and Miller (1950) and Berry et al. (1971).

Taste Panel

No significant ($P < .05$) differences among treatments were found for flavor, juiciness, tenderness and over-all acceptability after one, three, or five days of display. Mean taste panel scores ranged from 5.6 (5 = acceptable) to 7.9 (8 = desirable) (Appendix Table B).

Table 9. Effect of Film, Freezing-Packaging Sequence, Display Freezer and Display Time on Log Total Psychrotroph Counts[a]

Freezer Treatment	Log Psychrotroph Counts (per 10 cm^2)					
	Day 1		Day 3		Day 5	
(Freezing-Packaging Sequence)	Iolon	241	Iolon	241	Iolon	241
Spot (Fz-Pkg)	3.36	3.01	2.01	1.97	2.10	1.84
Upright (Fz-Pkg)	2.36	2.52	1.36	1.54	1.74	1.93
Open Top (Fz-Pkg)	2.82	3.33	1.77	2.45	2.18	1.98
Open Top (Pkg-Fz)	2.62	3.06	1.75	2.20	2.05	1.44
Film Means	2.79	2.98	1.72	2.04	2.02	1.80

[a]No significant differences ($P < .05$).

Table 10. Effect of Film, Freezing-Packaging Sequence, Display Freezer and Display Time on Mean % Display Loss[a]

Freezer Treatment	% Display Loss					
	Day 1		Day 3		Day 5	
(Freezing-Packaging Sequence)	Iolon	241	Iolon	241	Iolon	241
Spot (Fz-Pkg)	0.92	2.53	0.92	0.0	0.72	0.98
Upright (Fz-Pkg)	0.72	2.26	1.63	1.39	1.55	0.83
Open Top (Fz-Pkg)	1.68	3.53	1.11	1.52	1.55	0.88
Open Top (Pkg-Fz)	2.50	1.31	0.00	2.80	3.18	0.64
Film Means	1.46	2.41	0.92	1.43	1.75	0.83

[a]No significant differences ($P < .05$).

Table 11. Effect of Film, Freezing-Packaging Sequence, Display Freezer and Display Time on Mean % Cooking Loss

Freezer Treatment	% Cooking Loss					
	Day 1		Day 3		Day 5	
(Freezing-Packaging Sequence)	Iolon	241	Iolon	241	Iolon	241
Spot (Fz-Pkg)	22.89[b]	15.84[a]	20.19	21.08	21.42	24.57
Upright (Fz-Pkg)	21.44[b]	18.24[a]	18.50	20.30	22.93	22.73
Open Top (Fz-Pkg)	18.01[a]	16.40[a]	20.38	20.08	22.30	22.14
Open Top (Pkg-Fz)	16.90[a]	17.36[a]	20.32	17.71	22.17	22.26
Film Means	19.81[d]	16.96[c]	19.85	19.79	22.20	22.92

[a,b]Treatment means by display days bearing same or no superscript letters do not differ significantly ($P < .05$).

[c,d]Film means by display days bearing same or no superscript letter do not differ significantly ($P < .05$).

Summary

Color, display and cooking loss, microbiology and taste panel qualities were used to evaluate two packaging films, freezing-packaging sequence and three display freezers. Six replications utilizing 144 lamb chops were cut by the band saw. Frozen-packaged chops were crust frozen by liquid nitrogen vapor and warmed on the surface prior to skin tight packaging; whereas, package-frozen chops were skin tight packaged before crust freezing.

Lamb chops displayed in the upright freezer display had more desirable color as indicated by higher mean % reflectance at 630 nm and by visual appraisal. Reflectance readings at 630 nm for chops in 241 film were significantly ($P < .05$) more desirable than for chops in Iolon film. Although visual scores tend to support this, visual differences were not significant. Visual scores indicate that freezing and warming the meat surface prior to packaging produced greater color acceptability than packaging before freezing.

After one day of display, chops packaged in 241 and displayed in either the spot or upright display freezer had significantly ($P < .05$) less cooking loss than Iolon packaged chops displayed in the same cases, but no differences were apparent after three and five days of display.

No differences were found among the treatments for plate counts, total psychrotroph counts, display weight loss and taste panel scores for flavor, juiciness, tenderness and over-all acceptability.

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Chapter V

GENERAL SUMMARY

As the meat industry moves toward centralized processing, distribution in frozen form seems a logical link between meat processors and retailers. Lamb marketing is especially suited to centralized processing and frozen distribution to retail markets since lamb tends to be a seasonal or unavailable product in less populated areas because of low and inconsistent demand.

Color, display and cooking loss, microbiology and taste panel qualities were used to evaluate freezing and packaging systems, freezing-packaging sequence and display freezers for frozen lamb chops.

In study I, chops from choice loins were cut 2.54 cm thick either by band saw or Bettcher power cleaver and allowed to bloom 15 minutes before packaging. Treatments involved fresh, frozen-thawed and frozen lamb chops packaged in polyvinylchloride, Iolon or 241 film. After skin tight packaging, frozen-thawed and frozen chops were crust frozen with liquid nitrogen vapor.

In study II, chops from choice loins were cut 2.54 cm thick by band saw and allowed to bloom 15 minutes. Frozen-packaged chops were crust frozen by liquid nitrogen vapor and warmed on the surface prior to skin tight packaging in 241 or Iolon, whereas packaged-frozen chops were skin tight packaged before crust freezing. Chops were then placed in the pre-assigned spot, upright or open top case.

Frozen chops had brighter red color as indicated by visual scores and % reflectance at 630 nm, which may be due to the slight bleaching effect on the meat surface and higher reflectance of frozen muscle.

Frozen-thawed chops had the least desirable color as evidenced by lower % reflectance at 630 nm and by visual scores. Lamb chops displayed in the upright display freezer had more desirable color as indicated by both higher mean % reflectance at 630 nm and by visual appraisal. Better color scores for chops packaged in film 241 than Iolon film may have been related to its higher oxygen permeability. Visual color scores suggest that freezing and warming the meat surface prior to packaging produces greater color acceptability than packaging before freezing.

Rapid freezing and frozen storage significantly ($P < .05$) lowered plate counts after one or five days of display. However, no significant differences were found among packaging film, freezing-packaging sequence and freezer display treatments for plate counts or total psychrotroph counts.

Frozen-thawed chops produced the greatest cooking loss after one day of display but frozen chops had more cooking loss than other treatments after three or five display days. On day one of display, chops packaged in 241 and displayed in either the spot or upright freezer display had significantly ($P < .05$) less cooking loss than Iolon packaged chops displayed in the spot or upright case, but no differences were apparent after three or five days of display.

No significant ($P < .05$) differences were found for display weight loss or taste panel evaluation of flavor, juiciness, tenderness or overall acceptance.

APPENDIX

Appendix Table A. Mean Taste Panel Scores for Fresh, Frozen-Thawed and Frozen Lamb Chops

	Flavor			Juiciness			Tenderness			Over-all Acceptability		
Treatment	1	3	5	1	3	5	1	3	5	1	3	5
Tray-Overwrap	6.4	6.4	6.8	6.7	6.6[a]	7.3	6.4	6.1	6.9	6.4	6.6[a,b]	6.6
Iolon Fresh	6.5	6.9	7.0	6.5	6.6[a,b]	6.8	5.9	6.6	6.7	6.2	6.6[a,b]	6.8
Iolon Frozen-Thawed	6.7	6.9	6.6	6.3	6.3[a,b]	6.7	6.4	7.2	7.1	6.5	6.7[a,b]	6.6
241 Fresh	6.8	6.2	6.7	6.6	6.8[a]	7.3	6.5	6.1	6.1	6.7	6.1[b,c]	6.6
241 Frozen-Thawed	6.5	6.9	6.0	5.8	6.5[a,b]	6.3	6.6	6.6	6.8	6.3	6.9[a]	6.2
Iolon Frozen	6.8	6.4	6.9	6.2	5.6[b,c]	6.7	6.5	5.7	6.4	6.6	6.0[b,c]	6.6
241 Frozen	6.8	6.4	6.8	5.6	5.2[c]	6.4	6.1	5.6	6.5	6.1	5.8[c]	6.6

[a,b,c]Means within same column bearing same or no superscript letters do not differ significantly ($P < .05$).

Appendix Table B. The Effect of Film, Freezing-Packaging Sequence and Display Freezer on Taste Panel Evaluation[a]

	Flavor			Juiciness			Tenderness			Over-all Acceptability		
Treatment	1	3	5	1	3	5	1	3	5	1	3	5
Iolon/Spot/Fz-Pkg	7.9	7.7	7.7	6.7	6.8	7.1	7.2	7.4	6.9	7.4	7.5	7.3
241/Spot/Fz-Pkg	7.2	6.9	7.1	6.5	6.0	5.6	7.2	6.8	6.2	7.0	6.6	6.5
Iolon/Upright/Fz-Pkg	7.5	7.6	7.3	6.4	6.6	6.2	6.6	7.0	6.5	7.0	7.4	6.8
241/Upright/Fz-Pkg	7.8	7.6	7.6	6.9	6.7	6.0	7.3	7.0	6.6	7.4	7.2	7.1
Iolon/Open Top/Fz-Pkg	7.7	7.4	7.0	6.9	7.0	6.2	7.2	6.9	6.8	7.3	7.2	6.7
241/Open Top/Fz-Pkg	7.4	7.1	7.6	6.5	6.2	6.3	6.9	6.7	6.6	6.8	6.7	7.0
Iolon/Open Top/Pkg-Fz	7.7	7.6	7.4	7.0	6.6	6.4	7.5	7.0	6.6	7.2	7.2	7.0
241/Open Top/Pkg-Fz	7.1	7.2	7.3	6.8	6.6	6.1	6.9	6.9	6.8	6.9	7.0	6.9

[a]No significant differences ($P < .05$)

AN EVALUATION OF DIFFERENT PACKAGING, PROCESSING AND DISPLAY SYSTEMS FOR FROZEN LAMB CHOPS

By

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B. S., University of Tennessee, 1972

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

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Frozen chops had brighter red color as indicated by visual scores and % reflectance at 630 nm, which may be due to the slight bleaching effect on the meat surface and higher reflectance of frozen muscle. Frozen-thawed chops had the least desirable color as evidenced by lower % reflectance at 630 nm and by visual scores. Lamb chops displayed in the upright display freezer had a more desirable color as indicated by both higher mean % reflectance at 630 nm and by visual appraisal, which is probably due to the orientation of lamb chops to light source. Better

color scores for chops packaged in film 241 than Iolon film may have been related to its higher oxygen permeability. Visual color scores suggest that freezing and warming the meat surface prior to packaging produces greater color acceptability than packaging before freezing.

Rapid freezing and frozen storage significantly ($P < .05$) lowered plate counts after one or five days of display. However, no significant differences were found among packaging film, freezing-packaging sequence and freezer display treatments for plate counts or total psychrotroph counts.

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No significant ($P < .05$) differences were found for display weight loss or taste panel evaluation of flavor, juiciness, tenderness or overall acceptance.