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

by

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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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