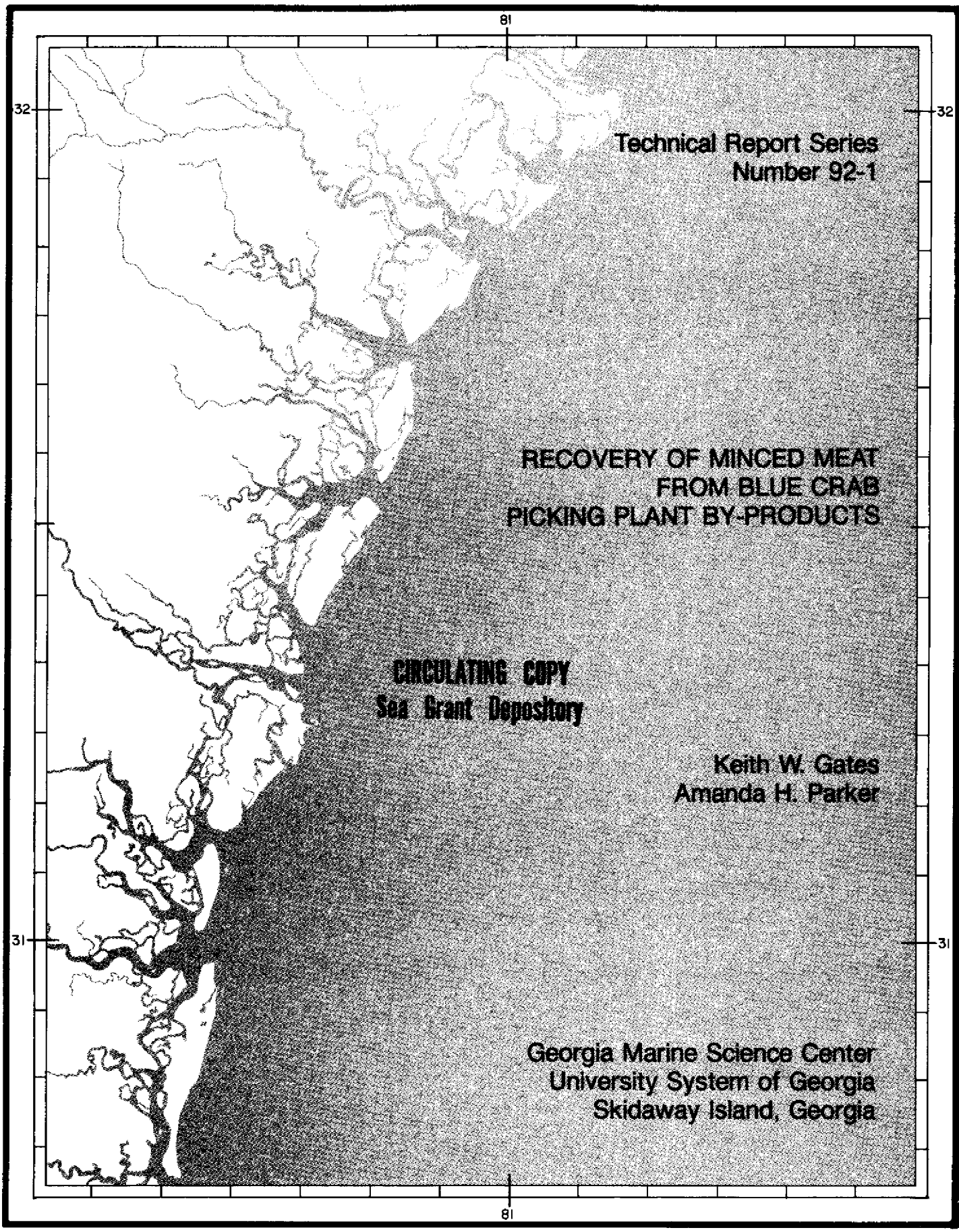

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RECOVERY OF MINCED MEAT FROM BLUE CRAB PICKING PLANT BY-PRODUCTS

Keith W. Gates
Amanda H. Parker

Georgia Marine Science Center
University System of Georgia
Skidaway Island, Georgia

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Keith W. Gates and Amanda H. Parker
University of Georgia
Marine Extension Service
715 Bay Street
Brunswick, GA 31520
912-264-7268

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ABSTRACT

Blue crab by-products extracted with a Baader deboner yielded the following minced meats: white, 3.18%; mixed, 10.71%; claw, 6.39%; and leg, 2.62%. Sensory profiles showed distinct visual, textural, and flavor attributes for each meat. Minced meat plate counts ranged from 10^5 to 10^7 CFU/g. Extraction within 1.5 hours of picking or icing of by-products stabilized plate counts.

Hunter L, a, b values showed that meat pasteurized at 177°F blued significantly less than meat pasteurized at 182°F (83.3°C). Treatment with citric acid-phosphate buffer further reduced bluing at 177°F (80.5°C). Mixed minced meat and minced claw meat pasteurized at 182°F (83.3°C) in low-density polyethylene tubes darkened significantly and developed "off" odors and flavors during ten months of frozen storage. Buffered and unbuffered minced meat pasteurized at 177°F (80.5°C) in aluminum cans failed to develop "off" odors or flavors during eleven months of frozen storage. Buffered and unbuffered meats darkened during storage, however buffered meat was whiter and blued less than unbuffered meat.

Except for intermittent spoilage that was attributed to faulty cans, pasteurized minced meat maintained acceptable microbiological quality for thirteen months of refrigerated storage at < 35°F (< 1.7°C). ACS Spectro Sensor readings of frozen minced meat showed that the addition of phosphate citric acid buffer prior to pasteurization improved the appearance of the meat. Experimental extraction of mixed minced meat with 19 combinations of solvents showed that product treated with bicarbonate/water/water, three water washes, or bicarbonate/SPD/sodium chloride significantly lightened meat color as determined by ACS Spectro Sensor readings. However, the sensory panel did not determine any significant differences in meat color following solvent extractions.

INTRODUCTION

Recovering and marketing products of higher value from fishery wastes can reduce rising disposal costs and increase profits and employment for the nation's seafood industry. The blue crab industry, which generates approximately 180 million pounds of crab by-products annually, has been particularly vulnerable to waste disposal problems (Murray and DuPaul, 1981). Steam-processed blue crabs yield approximately 10% picked meat by weight. Remaining by-products are either discarded or processed for crab meal, which sells for $100 to $150 per ton (Murray and DuPaul, 1981). Mechanical extraction of minced meat from crab picking by-products could recover an additional 15% to 20% of edible meat. Nationally, annual recovery of minced crab meat could approach 30 million pounds (Thompson, 1985). Minced meat sells for approximately $1.00 per pound and is used as an extender in deviled crab, seafood stuffings, soups, and chowders. Minced meat production at two crab plants that participated in the study increased from approximately 20,000 pounds per year to more than 400,000 pounds per year during the three-year investigation.

The grey-to-brown appearance and high microbial levels of minced meat limit its marketability. Minced meat produced in Georgia is packed in ring-sealed, five-pound, low-density polyethylene tubes. The tubes are pasteurized in hot water to reduce microbial levels, which further darkens the product. Most meat is sold as a frozen product. Processors market meat with poor knowledge of nutritional, sensory, and storage qualities. Improved quality would increase market demand, and new products could expand sales through production of white and claw meat analogs.

The Sea Grant research project described in this report was designed to improve the quality and appearance of minced blue crab meat. Yields, chemical, sensory, microbiological, and nutritional qualities were determined for meats extracted from picking-room by-products. In-plant methods to reduce microbial

loads were investigated. Low-temperature pasteurization and chemical additives were evaluated for potential reduction of heat-related darkening or "bluing." Chemical, sensory, microbiological, and nutritional changes in mixed minced meat and minced claw meat pasteurized at 182°F (83.3°C) were monitored monthly during frozen storage at less than -4°F (-20°C). Mixed minced meat pasteurized at a reduced temperature, 177°F (80.5°C), with and without citric acid phosphate buffer was also monitored during frozen storage at less than -4°F (-20°C).

Mixed minced meat used in the refrigerated storage portion of the study was pasteurized in eight-ounce aluminum cans at 177°F (80.5°C). Minced meat and meat treated with phosphate buffer were stored at <35°F (<1.7°C). Cans were sampled monthly for aerobic plate counts, Hunter L, a, b and Stensby WI color values, and proximate composition during 13 months of refrigerated storage.

Color improvement of extracted minced meats would greatly expand market opportunities for the products. Color extraction and bleaching techniques were adapted from procedures developed for bleaching fish flesh, producing fish protein concentrates, and manufacturing surimi. We investigated extraction of mixed minced meat with a series of 19 solvent combinations to evaluate methods to decolorize or lighten the product. Mixed minced meat was extracted using the solvents, and product color was evaluated in terms of Hunter L,a,b values, WI index, and sensory panel hedonic perception of minced meat color.

METHODS

By-Product Extraction

Minced meat was extracted from picking-room by-products of mechanically-backed (C. and K. Lord Backing Machine, Cambridge, MD), hand-picked, steam-retorted blue crabs using a Baader 694 deboning machine (Baader North America Corp., New Bedford, MA). Drum perforations were 1.3 mm in diameter. Two blue crab processors cooperated by providing plant time and equipment for the project. Picking-room by-products were separated into four components to evaluate extracted meat types and yields for the following materials:

1. Mixed minced meat - recovered from all picking-room by-products except claws
2. Minced white meat - recovered from "slabs" removed by the pickers' first dorsal cut, containing only white body meat
3. Minced leg meat - recovered from separated walking legs and swimming legs
4. Minced claw meat - recovered from separated claws. Whole claws are separated by hand or machine. Commercially meat is extracted from whole claws when there are more claws available for picking than can be accommodated by the hand-picking operation.

Analyses

Chemical and nutritional parameters determined in duplicate for minced meat samples included: percent moisture, percent Kjeldahl protein, percent ash, and percent fat (Williams, 1984). Microbiological quality was assessed through duplicate standard aerobic plate counts, enterococci plate counts, MPN total coliforms, MPN E.coli, and MPN coagulase positive staphylococci analyses (Food and Drug Administration, 1978; Speck, 1984). An ACS Spectro Sensor (supplied by

the O'Brien Corp., Brunswick, GA) was used to determine minced meat Hunter L, a, b color values (Hunter and Harold, 1987). Whiteness index (WI) was calculated according to Stensby (1967):

$$WI = L - 3b + 3a$$

Sensory Panel

A trained five-member sensory panel determined appearance, flavor, odor, and textural characteristics of extracted minced meat (Cardello, 1981; Civille and Liska, 1975; Civille and Szczesniak, 1973; Gates et al., 1984a; Jellinek, 1985). Sensory profiles were developed for unpasteurized and pasteurized minced meat samples. Appearance and odor profile descriptors were defined as follows:

1. Bluing: No obvious bluing is 0, 100% bluing is 6.
2. Wet-to-dry appearance: 0 is dry, 6 is free liquid draining from sample.
3. Ammonia odor: 0 represents no detectable odor, while 6 is the odor of free ammonia that would strongly irritate the nose and eyes.
4. Cooked-crab odor: 0 is no detectable odor, 6 is an overwhelming crab aroma reminiscent of the odors evolved from steaming crabs.
5. Putrid: 0 is no detectable odor, 6 is the strong odor associated with rotten meat.
6. Fish or trimethylamine odor: 0 is no detectable odor, while 6 indicates the " fish" odor associated with old fish that are getting "off" and are barely edible.
7. Cereal odor: 0 is no detectable odor, while 6 indicates a strong cereal-bread-yeasty aroma.

The following taste and textural profiles were developed for pasteurized minced crab meat:

1. Moistness: The perceived degree of oil and/or water in the sample during chewing. 0 is a very dry sample, 6 indicates free liquid readily oozing from the sample.
2. Fibrousness: The perceived degree (number x size) of fibers evident during mastication. 0 is no fibers evident, 6 indicates many large fibers.
3. Adhesiveness: The force required to remove material that adheres to the mouth during the normal eating process (0 = no adhesion; 3 = cream cheese; 6 = peanut butter).
4. Chewiness: The length of time required to masticate a sample at constant rate of force to reduce it to a consistency suitable for swallowing (0 = Rye bread; 2 = Jujubes; 4 = Black cow candy; 6 = Tootsie Rolls).
5. Particle size: Average size of particles detected during mastication (0 = smooth; 1 = chalky; 2 = gritty; 3 = grainy; 4 = coarse; 6 = chunky).
6. Cooked-crab taste: Relative strength of crab taste. 0 = none detected, 6 = overwhelming crab taste.
7. Astringent: 0 = none detected, 6 = mouth feel and taste of pure alum.
8. Sourness: Relative strength of acidic components, 0 = none detected, 6 = pure lemon juice or vinegar.
9. Rancidity: The aftertaste associated with country ham. 0 = none detected, 6 = objectionable rancidity (old country ham).
10. Freezer-burn: The taste associated with a stale refrigerator or freezer that has been used to store food. 0 = none detected, 6 = overwhelming taste.
11. Old-seafood flavor: Aromatics and tastes associated with cooked seafood that is getting "off" but still acceptable, 0 = none detected, 6 = overwhelming taste of seafood that has developed strong "off" flavors and is barely edible.

Staff members who developed sensory profile descriptors served as the minced meat evaluation panel. Members were presented with coded samples and asked to rate each descriptor numerically on a printed ratings form. Panelists were supplied with the preceding list of sensory descriptors at each session.

Picking-Room Microbiological Analyses and Pasteurization

Bacterial levels in mixed picking-room by-products were evaluated during four hours of iced- or room-temperature storage to determine the most effective holding condition and maximum acceptable storage period before extraction. Pasteurization times, temperatures, and F-values were determined for meat packed in five-pound, low-density, polyethylene tubes using a Digitec temperature recorder linked with an IBM-XT (Gates et al., 1984b). Initial pasteurization temperatures were reduced to 182°F (83.3°C), because processors noted excessive bluing of meat pasteurized at 186°F (85.5°C). Previous studies have shown that lower pasteurization temperatures have reduced bluing of hand-picked meat (Boon, 1975; Gates et al., 1984b; Strasser et al., 1971; Waters, 1971). Product color was evaluated by the sensory panel and by Hunter L, a, b color values and Stensby's Whiteness Index (WI) values (Boon, 1975; Strasser et al., 1971; Waters, 1971; Stensby, 1967).

Effects of low-temperature pasteurization, 177°F (80.5°C), and bluing inhibitors on minced meat color were determined for mixed minced and minced white meat samples pasteurized in eight-ounce aluminum cans. The following buffer developed by the National Marine Fisheries Service was used in the additive portion of the study (Waters, 1971): Na_2HPO_4, 0.73 oz (20.79 g); $H_3C_6H_5O_7$, 0.57 oz (16.64 g); and NaCl, 0.78 oz (21.99 g). Sodium phosphate, citric acid, and sodium chloride were diluted to 33.8 oz (1000 ml) with deionized water to complete the buffer. Five low-temperature pasteurization treatments of minced white meat and mixed minced meat were evaluated by pasteurizing meat in eight-ounce aluminum cans at 177°F (80.5°C):

1. 8 ounces (226.8 g) of minced meat
2. 8 ounces (226.8 g) of minced meat plus 2.2 oz (64 ml) buffer that was poured on top of the meat after it had been packed into the can
3. 8 ounces (226.8 g) of minced meat plus 2.2 oz (64 ml) buffer that was well mixed by stirring it into the meat after it was packed into the can
4. 8 ounces (226.8 g) of minced meat plus 3.1 oz (91 ml) buffer that was poured on top of the meat after the meat had been packed into the can
5. 8 ounces (226.8 g) of minced meat plus 3.1 oz (91 ml) buffer that was well mixed by stirring it into the meat after it was packed into the can.

Buffer was either poured into a can of meat without mixing or thoroughly stirred into the meat prior to sealing. Meat was pasteurized for three hours at 177°F (80.5°C) to F_{185}^{16} = 37.65 minutes. Cooling was 1.5 hours in an ice slurry at 37.4°F (3°C) to a final temperature equal to or less than 40°F (4.4°C). Three cans of crab meat were composited for duplicate chemical, microbiological, color, and sensory analyses following pasteurization.

Frozen Storage In Polyethylene Tubes

Mixed minced meat and minced claw meat used for the frozen-storage study were packaged in 5 mil, low-density, polyethylene tubes containing approximately one pound of meat. Commercial tubes containing only one pound of meat, instead of five pounds of meat, were used to reduce storage requirements and meat costs. Stored one-pound tubes were shorter in length than five-pound tubes, but had the same cross-sectional area. Tubes were sealed at each end with steel rings, pasteurized in a hot water bath at 182°F (83.3°C) for 180 minutes, and cooled in an ice slurry for 90 minutes to less than or equal to 40°F (4.4°C). The mean F_{185}^{16} value was 44. Meat was blast-frozen at -11.2°F (-24°C). Samples were stored in

a walk-in freezer at less than -4°F (-20°C). Chemical, sensory, microbiological, and nutritional changes were monitored monthly for ten months. Three tubes of meat were composited each month for duplicate chemical, color, and microbiological analyses and sensory panel evaluations.

Frozen Storage In Aluminum Cans

Mixed minced meat used for buffered frozen storage tests was pasteurized in eight-ounce aluminum cans at 177°F (80.5°C) for three hours to F_{185}^{16} = 37.65 minutes. Cooling was 1.5 hours in an ice slurry at 37.4°F (3°C). Cans were packed with 8 oz (226.8 g) of minced meat or 8 oz (220.8 g) of minced meat mixed with 2.2 oz (64 ml) of citric acid-phosphate buffer described previously. Frozen cans of meat were held in a walk-in freezer at -4°F (-20°C) for eleven months. Three cans of each sample were composited monthly for chemical, sensory, microbiological, and color analyses. All analyses were completed in duplicate.

Refrigerated Storage In Aluminum Cans

Mixed minced meat used in the refrigerated storage portion of the study was pasteurized in eight-ounce aluminum cans at 177°F (80.5°C) for three hours to F_{185}^{16} = 37.65 minutes. Cooling was 1.5 hours in an ice slurry at 37.4°F (3°C) as previously described for the frozen storage of eight-ounce cans. Twenty-five pounds (11.3 kg) of mixed minced meat was mixed with 108 oz (3.2 l) of citric acid phosphate buffer prior to packing in 50 eight-ounce cans. Untreated mixed minced meat was also packed in 50 aluminum cans. Both products were held in refrigerated storage at <35°F (<1.7°C). Three cans of each sample were composited monthly for aerobic plate counts, Hunter L, a, b and Stensby WI color values, and proximate composition during 13 months of refrigerated storage. Analyses were completed in duplicate.

Color Extraction

Color extraction and bleaching techniques were adapted from those used in the bleaching of fish flesh, development of fish protein concentrates, and surimi processing technology (Banks and Morgan, 1978; Braid 1976; Guttmann and Vandenheuvel, 1957; Idler, 1968; Jauregui and Baker 1980; Thrash, 1983). Mixed minced meat was washed with a series of solvents to determine the ability of solvents to decolorize or lighten the product. Mixed minced meat (10 g) was combined with 30 ml of solvent and mixed. The meat/solvent mixture was centrifuged to remove solvent and any extracted color. Product color was evaluated in terms of Hunter L, a, b values, WI index, and sensory panel hedonic perception of minced meat. Sensory color was evaluated on an increasing scale of 0 to 6 with 6 representing the most desirable. Solvent 1/solvent 2 indicates that the meat was extracted first by solvent 1 followed by solvent 2. Minced meat was extracted with the following solvents or combination of solvents:

1. Unwashed control
2. Cold water
3. 2x with cold water
4. 0.5% sodium bicarbonate
5. Bicarbonate/water
6. 0.05% sodium tripolyphosphate (STP)
7. 0.05% sodium tripolyphosphate dibasic (SPD)
8. 0.3% sodium chloride (NaCl)
9. Cold ethanol
10. Bicarbonate/Nacl
11. Bicarbonate/STP/NaCl
12. Bicarbonate/SPD/NaCl
13. Bicarbonate/ethanol
14. Ethanol/water
15. 3x with cold water
16. Bicarbonate/STP/NaCl/water

17. Bicarbonate/SPD/NaCl/water
18. Bicarbonate/water/water
19. Hot ethanol

Statistical Analyses

Chemical, sensory, microbiological, and color differences in minced meat samples were compared statistically using Personal Computer SAS (Joyner, 1985; Sasser, 1985). Differences among means were determined using the GLM procedure and Duncan's multiple-range test. Pearson's correlation procedure was used to determine significant correlations between storage month and measured parameters (Joyner, 1985). In the remainder of the paper, statistically significant differences among means at the 0.05 level will be indicated by "$p < 0.05$" following a statement of comparison.

RESULTS AND DISCUSSION

By-Product Extraction

Blue crab picking-room by-products were separated into four components prior to extraction with a Baader 694 machine. By-product types were: (1) "slabs," the portion of hand-picking by-product containing only white body meat; (2) mixed by-product that included all picking-room by-products but claws; (3) separated legs; and (4) separated claws. Minced meat yields based on the weight of an uncooked green crab were: white meat, 3.18%; mixed minced meat, 13.89% (10.71% if slabs are separated); minced leg, 2.62%; and minced claw, 6.39%. Total recoverable minced meat is approximately 22% of an uncooked crab's weight. Yields based on cooked by-product type as the starting point were: 76.63%, 59.45%, 40.44%, and 38.07% for "slab," mixed, leg, and claw by-products, respectively (Figure 1).

Mean proximate analyses of the four meat types are presented in Figure 2. Minced leg meat had higher moisture levels ($p < 0.05$) than white or claw mince. Moisture contents of minced leg and mixed minced meat were greater than minced claw meat ($p < 0.05$). Minced white meat moisture content was definitely less than that of minced leg meat ($p < 0.05$). Minced leg meat had a notably lower ash content than other meat samples ($p < 0.05$). Minced claw protein levels were greater (0.05) than mixed minced meat. Fat levels were low for all minced meats, but claw meat had less fat than leg meat ($p < 0.05$) which had lower fat levels than white or mixed minced meat ($p < 0.05$). Mixed minced meat had greater moisture-free ash content than other meats ($p < 0.05$), indicating greater shell content. Leg meat had higher moisture-free protein levels than mixed or white minced meat ($p < 0.05$).

Figure 2 presents mean Hunter color L, a, b, and Stensby's whiteness index (WI) results for the four meat types. Mean L values were significantly different

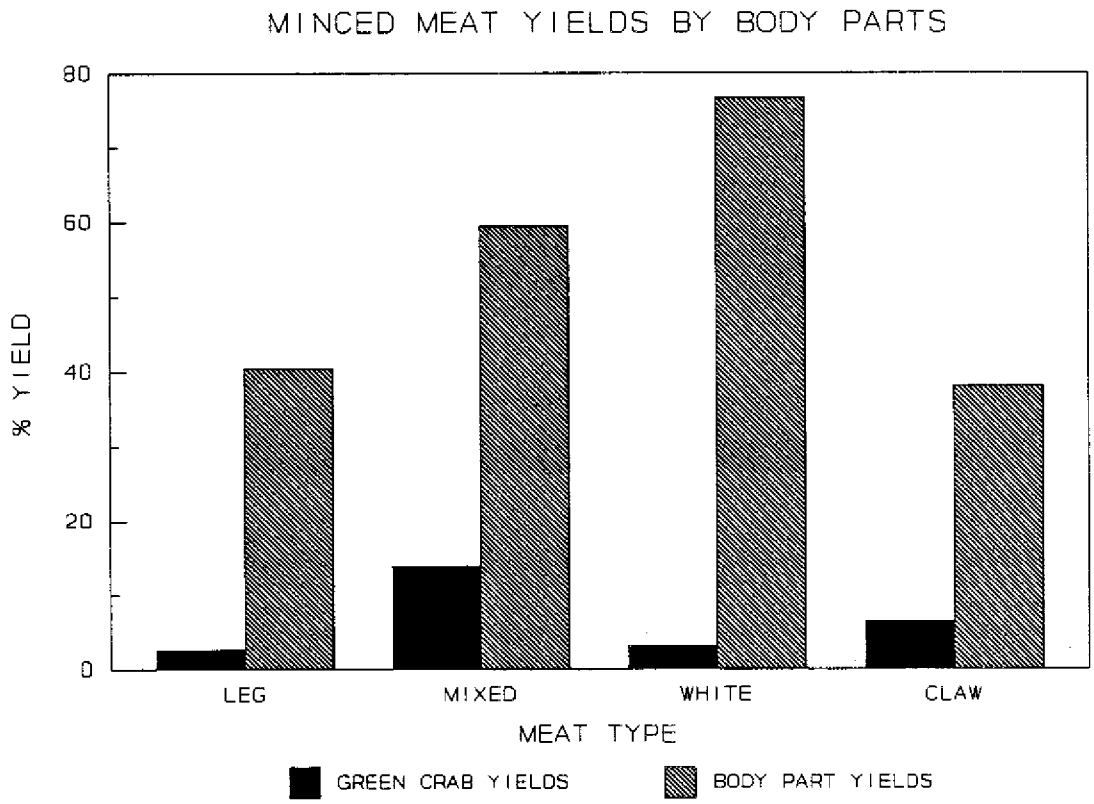


Figure 1. Mean minced meat by-product yields based on uncooked green crab starting weight and weight of by-products after cooking.

for all minced meats ($p < 0.05$). Order of decreasing whiteness by L value was: white, mixed, claw, and leg. WI values computed by Stensby's index reduce whiteness by three times the blue (b) value and increase it by three times the red (a) value. Claw and leg WI ratings were greater than white and mixed meat levels ($p < 0.05$), reflecting higher blue levels determined for mixed and white meats. Mean Hunter a values show mixed minced meat to be redder than other meats. Blue components of mixed and white minced meat are notably greater than blue components of claw and leg meat ($p < 0.05$).

Mean sensory appearance and odor profiles for minced meat samples are reported in Figure 3 ($p < 0.05$). Leg meat appeared to be more wet than white meat. Leg meat had stronger ammonia odors than white meat ($p < 0.05$). No

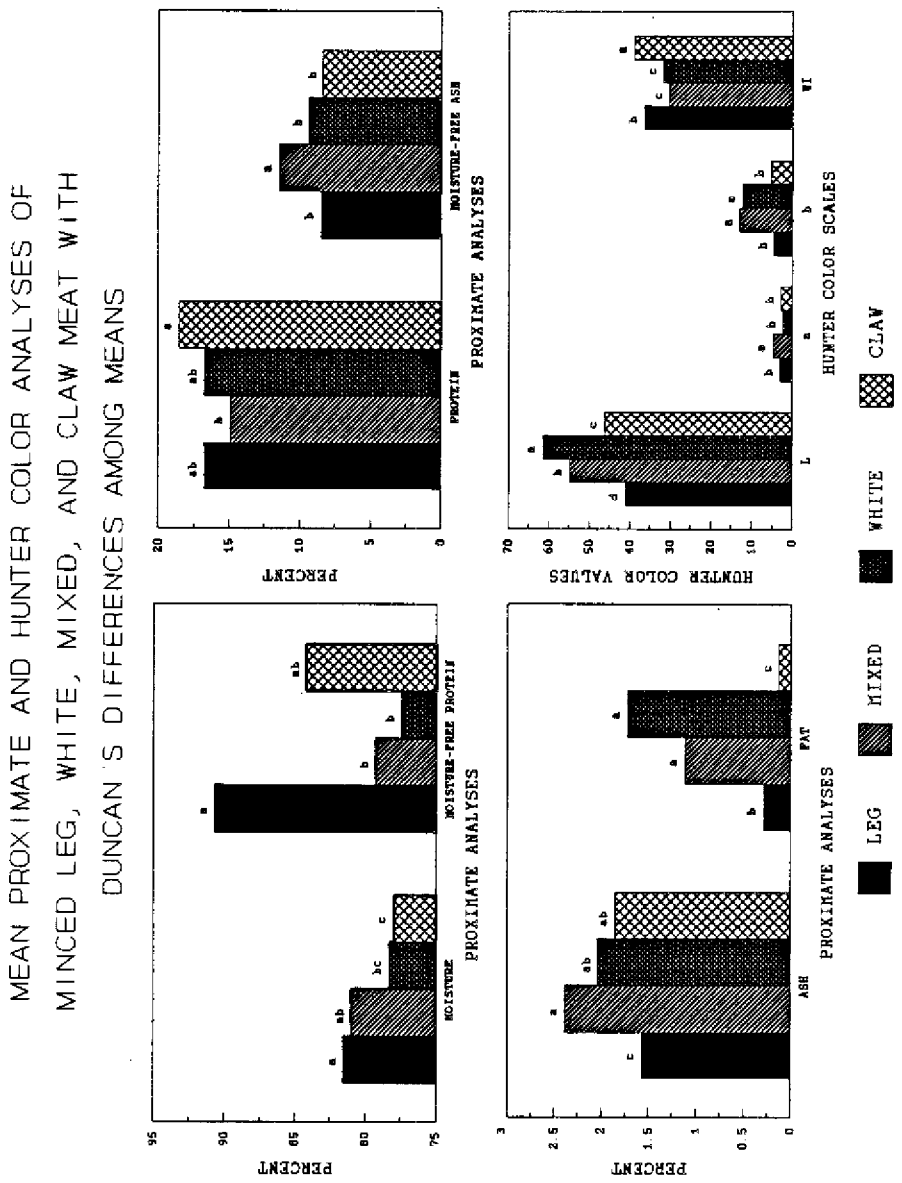


Figure 2. Proximate and Hunter color analyses of differences among leg, white, mixed, and claw minced meat. Meat types with the same letter above mean bars are not different ($p < 0.05$).

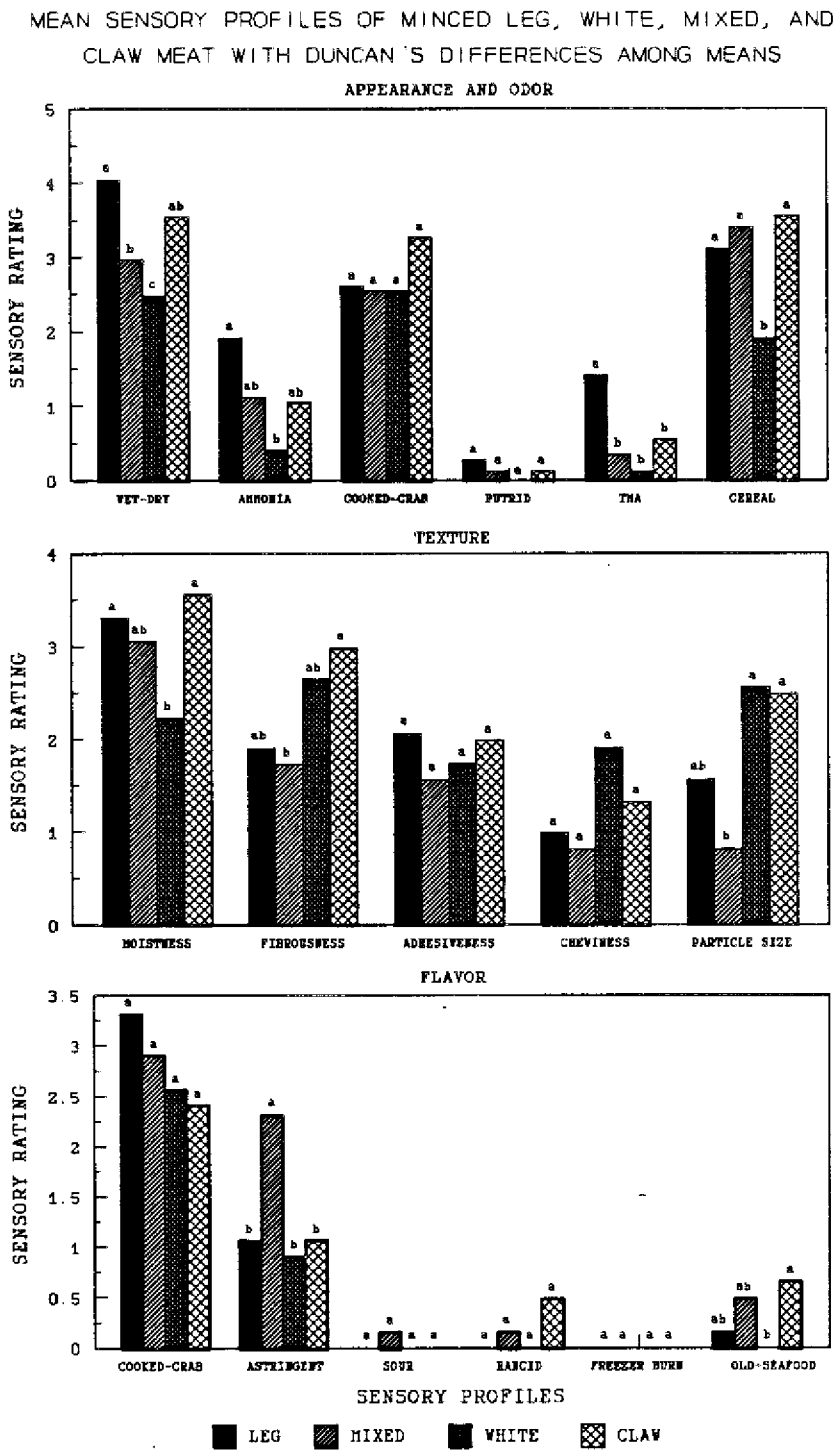


Figure 3. Sensory appearance, odor, texture, and flavor analyses of differences among leg, white, mixed, and claw minced meat. Meat types with the same letter above mean bars are not different ($p < 0.05$).

statistically significant differences were determined for cooked crab or putrid odors. Leg meat had considerably greater trimethylamine (TMA) odor ratings than other minced meat ($p < 0.05$). Cereal odor determined for white meat was definitely less intense than other meats ($p < 0.05$).

Textural profiles of minced meat determined by the sensory panel are presented in Figure 3. Claw and leg meat were more moist than white meat ($p < 0.05$). Claw meat was rated more fibrous than mixed minced meat ($p < 0.05$). No statistically significant differences were determined for adhesiveness or chewiness. Particle sizes of white and claw minces were distinctly larger than mixed minced meat ($p < 0.05$).

Mean flavor profiles for the four minced meats are shown in Figure 3. Mixed minced meat had a greater astringent feeling than other meat ($p < 0.05$). Old-seafood flavors were found at higher levels in claw meat than other minces ($p < 0.05$). No statistically significant differences were determined among minced meats for sour, rancid, freezer-burn, or old-seafood flavors.

Four meats with distinct chemical compositions, colors, flavors, and textures were extracted. Leg and mixed minced meat had the highest moisture contents. Ash contents were low, ranging from 1.57% for leg meat to 2.14% for mixed minced meat, indicating little shell contamination. Fat content was low, ranging from 0.12% to 1.73%. Mixed minced and white meat had higher fat contents than minced leg or minced claw meat. Minced claw had the highest protein content, 18.54%. "Slabs" produced a dry, white, textured mince; mixed by-product produced a moist, golden-brown mince; legs produced a smooth, flavorful, dark-brown meat; and claws produced a highly-textured, less-flavored, chewy, brown mince.

Picking-Room Microbiological Analyses and Pasteurization

Minced meat exhibited high microbial levels, ranging from 10^5 to 10^7 CFU/g. No statistically significant differences were determined among aerobic plate counts for the four meat types before pasteurization. Unpasteurized plate counts were higher than pasteurized plate counts ($p < 0.05$) (Figure 4). Pasteurized claw bacterial levels were greater than pasteurized leg populations ($p < 0.05$). Pasteurization at 182°F (83.3°C) ($F_{185}^{16} = 44$) reduced plate counts to less than 3,000 CFU per gram (Log 3.5 CFU/g) (Figure 4). No total coliform, *E. coli*, or coagulase positive staphylococci were detected in pasteurized meats. Hourly clean-up and sanitation of the Baader machine improved product quality; however, by-product microbial levels increased rapidly when held at room temperature (Figure 5). Extraction within 1.5 hours of picking showed little increase in microbial populations of mixed by-products. Microbial growth was controlled for extractions delayed beyond 1.5 hours by placing picking-room by-products within plastic bags and icing the bags at a ratio of 2:1 ice-to-product (Figure 5). By-product temperature dropped below 40°F (4.4°C) within 70 minutes of icing (Figure 6).

Pasteurization at 182°F (83.3°C) effectively reduced microbial levels for all minced meats (Figure 4); however, meats darkened following pasteurization. Hunter color L, a, b, and Stensby WI values before and after pasteurization are presented in Figure 7. Hunter L or whiteness decreased for all pasteurized meats (Figure 7), and significantly so for mixed, claw, and leg meat following pasteurization ($p < 0.05$). Stensby's WI values were definitely less for pasteurized white and leg meats ($p < 0.05$). Hunter a, or redness, decreased for all pasteurized samples except claw meat ($p < 0.05$) (Figure 7). Hunter b values decreased significantly for all pasteurized samples except claw meat, indicating increased levels of bluing ($p < 0.05$) (Figure 7).

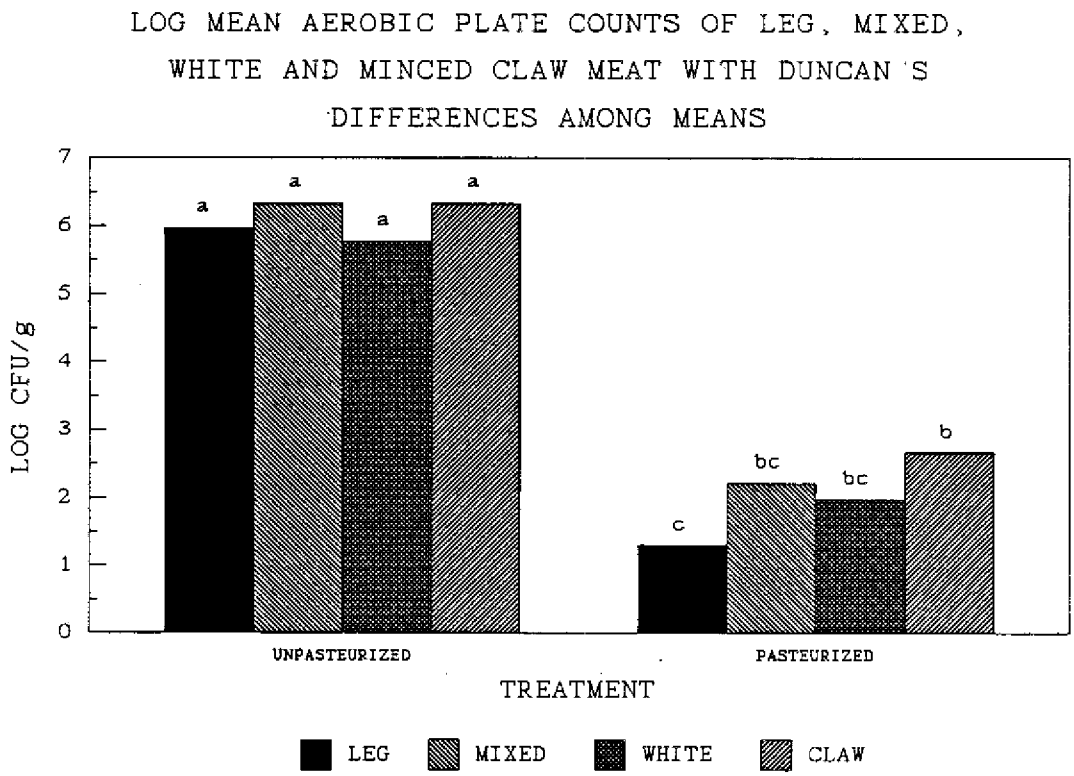


Figure 4. Log mean plate counts before and after pasteurization of leg, white, mixed and claw minced meat analyses of differences among means. Meat types with the same letter above mean bars are not different ($p < 0.05$).

Hunter color L, a, b, and Stensby WI values for minced white meat and mixed minced meat pasteurized at 177°F (80.5°C) and 182°F (83.3°C) are presented in Figure 8. Minced white meat pasteurized at 177°F (80.5°C) was not as blue as meat pasteurized at 182°F (83.3°C) ($p < 0.05$) as indicated by Hunter b values. Mixed minced meat pasteurized at 182°F (83.3°C) had a lower mean Hunter L value than meat pasteurized at 177°F (80.5°C) ($p < 0.05$) (Figure 8). Hunter L values show no statistically significant differences among buffered and unbuffered white meat samples cooked at 177°F (80.5°C) except for meat buffered with 2.2 oz (64 ml) of citric acid phosphate that was not mixed into the meat. The product was not as white as other pasteurized samples ($p < 0.05$) (Figure 9). WI values which combine L, a, and b levels showed meat treated with 2.2 oz (64 ml) of buffer

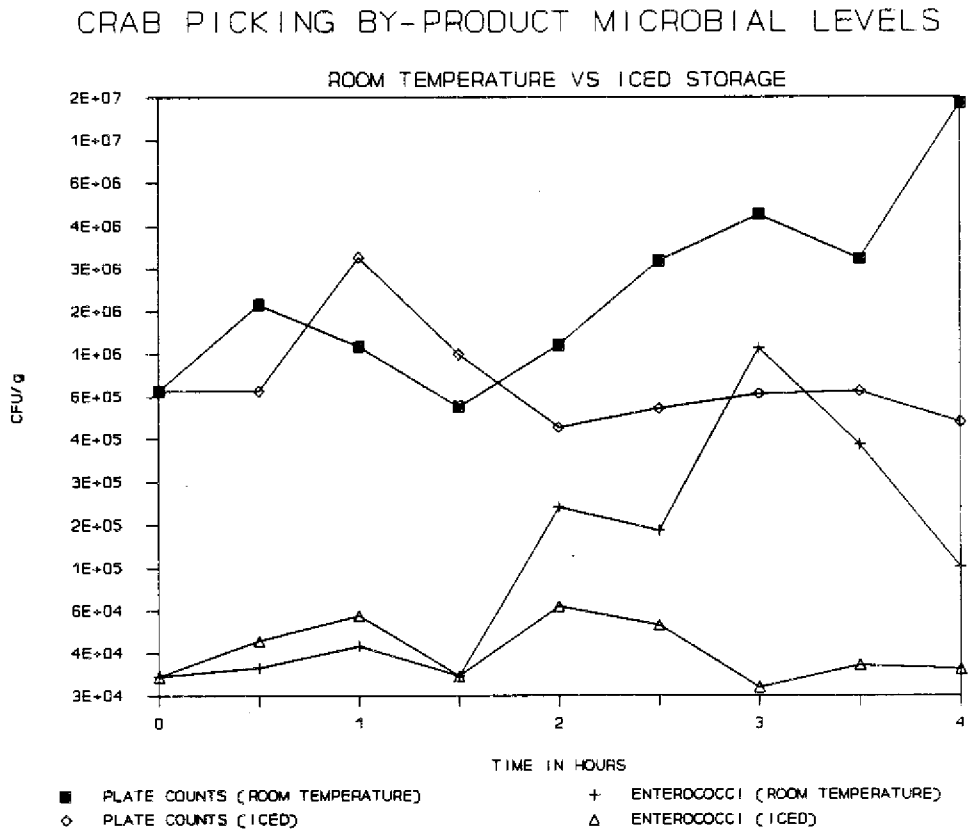


Figure 5. Mean microbial levels of mixed picking-room by-products held on ice and at room temperature.

(without mixing) to be the whitest sample. All pasteurized white meat samples had higher WI levels than unpasteurized meat. Hunter a values showed unpasteurized white meat and pasteurized white meat containing 3.1 oz (91 ml) of buffer to be more red than other pasteurized samples ($p < 0.05$). Pasteurized unbuffered white meat and pasteurized white meat treated with 2.2 oz (64 ml) of buffer that had not been mixed were definitely more red than other samples ($p < 0.05$) (Figure 9). Blue color levels, as shown by Hunter b values, were not significantly different for unpasteurized white meat and white meat treated with 3.1 oz (91 ml) of buffer prior to pasteurization at 177°F (80.5°C). White meat treated with 3.1 oz (91 ml) of buffer prior to pasteurization blued less than the following in order of increased bluing: white meat mixed with 2.2 oz (64 ml) buffer, unbuffered meat and meat mixed with 3.1 oz (91 ml) of buffer, and meat

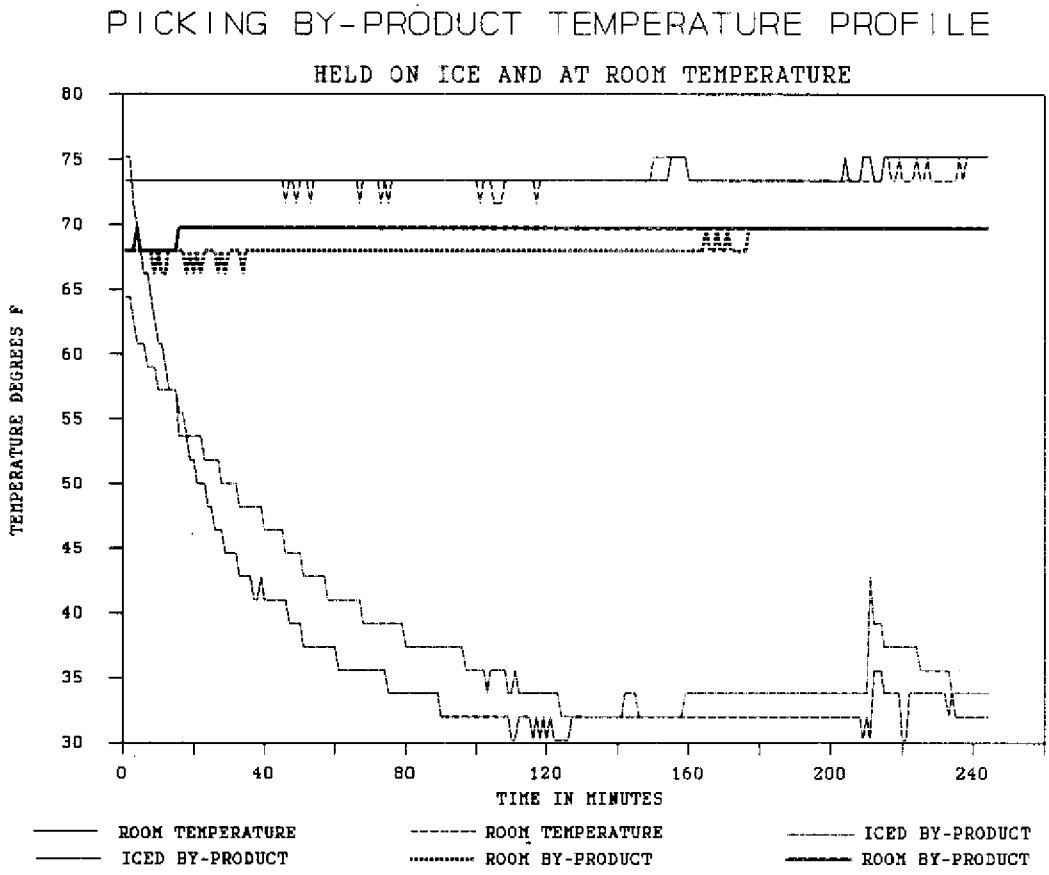


Figure 6. Temperatures of mixed picking-room by-products held on ice and at room temperature for four hours.

treated with 2.2 oz (64 ml) of buffer ($p < 0.05$) (Figure 9). Unpasteurized mixed minced meat and all buffered mixed minced meat samples pasteurized at 177°F (80.5°C) had higher L values than unbuffered mixed minced meat cooked at the same temperature (Figure 9). Stensby's whiteness index showed that unpasteurized mixed minced meat and pasteurized mixed minced meat treated with 2.2 oz (64 ml) and 3.1 oz (91 ml) of buffer to be definitely more white than unbuffered meat pasteurized at 177°F (80.5°C) ($p < 0.05$). Mixed minced meat mixed with 3.1 oz (91 ml) of buffer had the whitest appearance by Hunter L values while unmixed 3.1 oz (91 ml) buffered meat had the highest WI rating. Mixed minced meat mixed with 2.2 oz (64 ml) of buffer had the second highest Hunter L rating. Unpasteurized

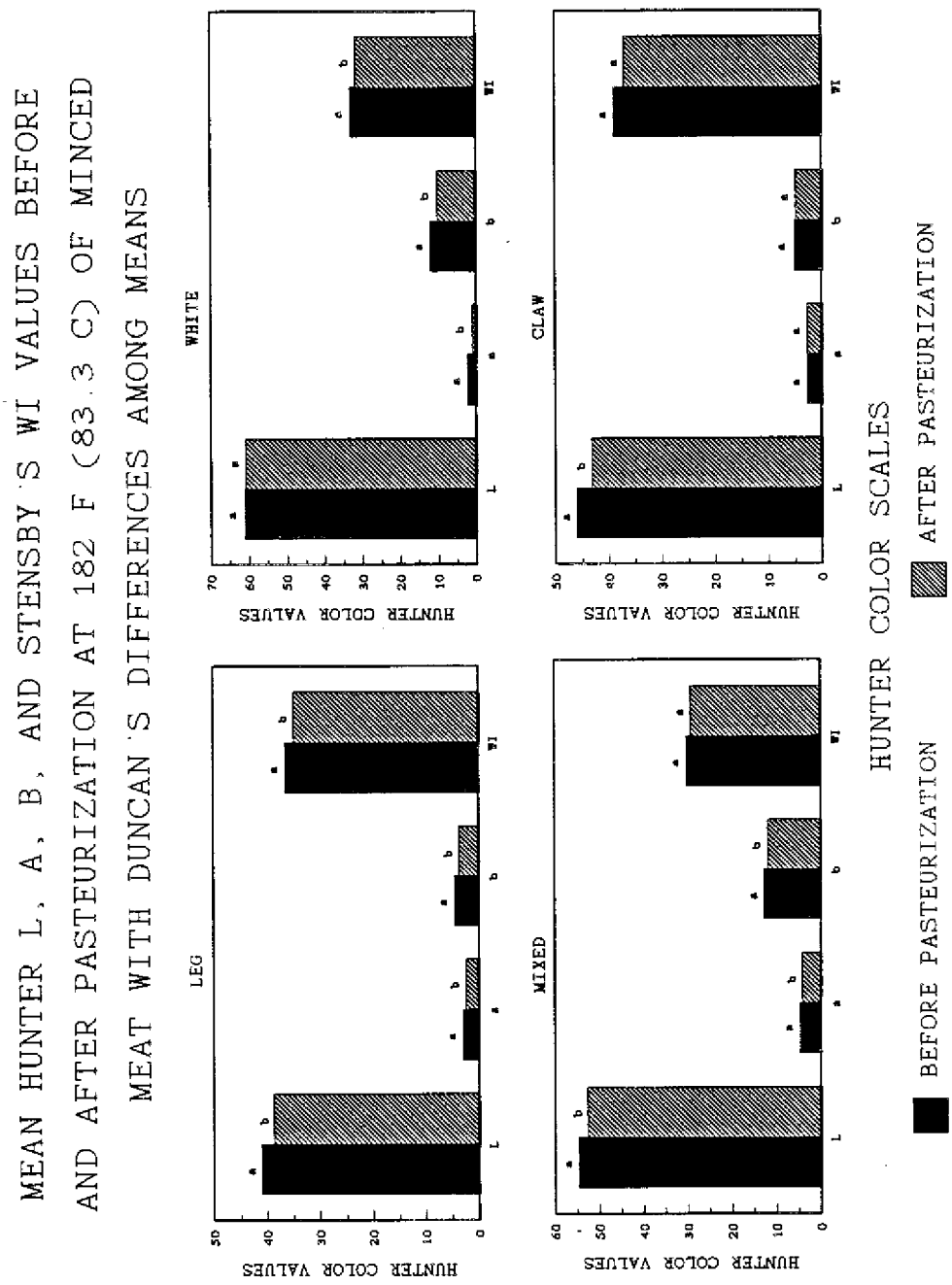


Figure 7. Color value analyses of differences among leg, white, mixed and claw minced meat before and after pasteurization at 182°F. Meat types with the same letter above mean bars are not different ($p < 0.05$).

and buffered mixed minced meat pasteurized at 177°F (80.5°C) had greater Hunter a or red components than unbuffered meat pasteurized at the same temperature ($p < 0.05$). Statistically significant differences among mixed minced meat Hunter a values were grouped in the following order of decreasing redness: mixed minced meat mixed with 2. oz (64 ml) of buffer, mixed and unmixed meat treated with 3.1 oz (91 ml) of buffer, unpasteurized meat and meat containing 2.2 oz (64 ml) of buffer, and unbuffered meat pasteurized at 177°F (80.5°C) ($p < 0.05$) (Figure 9). Addition of buffers to mixed minced meat definitely reduced bluing at 177°F (80.5°C) ($p < 0.05$). Unpasteurized meat and unbuffered meat had notably lower Hunter b values, indicating more bluing than all buffered treatments ($p < 0.05$). Mixed minced meat treated with 2.2 and 3.1 oz (64 and 91 ml) of buffer mixed into the meat were less blue than buffered meat that had not been thoroughly mixed ($p < 0.05$).

Pasteurization at the reduced temperature of 177°F (80.5°C) improved meat color for both white and mixed minced meat as indicated by Hunter L and b values. Color characteristics of white and mixed minced meat were improved by adding citric acid phosphate buffer when pasteurized at 177°F (80.5°C)($p < 0.05$). White meat containing 3.1 oz (91 ml) of buffer that was mixed or not mixed or containing 2.2 oz (64 ml) of buffer mixed into the meat was definitely less blue and less green than unbuffered white meat pasteurized at 177°F (80.5°C). All buffered mixed minced meat samples were notably more white, less green, and less blue than unbuffered minced meat pasteurized at 177°F (80.5°C). Mince containing 2.2 and 3.1 oz (64 and 91 ml) of phosphate buffer premixed into the meat produced the most favorable color characteristics. Mixed minced meat containing 3.1 oz (91 ml) of buffer without mixing had the highest WI rating. Pasteurization at 177°F (80.5°C) effectively reduced bacterial populations. Total aerobic plate counts for pasteurized mixed minced and minced claw meat ranged from none detected to 160 CFU per gram. No total coliform, *E. coli*, or coagulase positive staphylococci were detected.

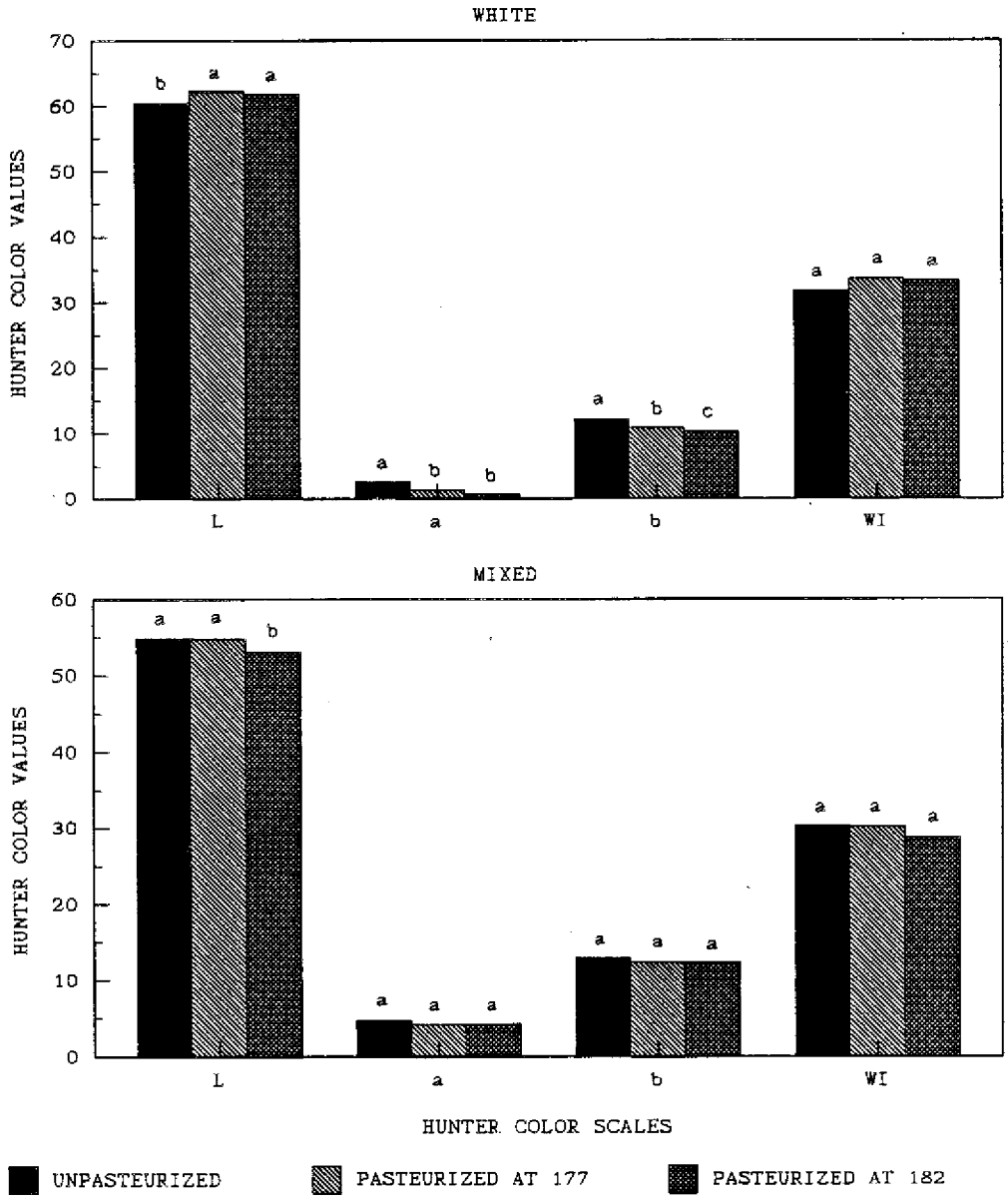


Figure 8. Color analyses of white and mixed minced meat pasteurized at 177°and 182°F. Meat types with the same letter above mean bars are not different ($p < 0.05$).

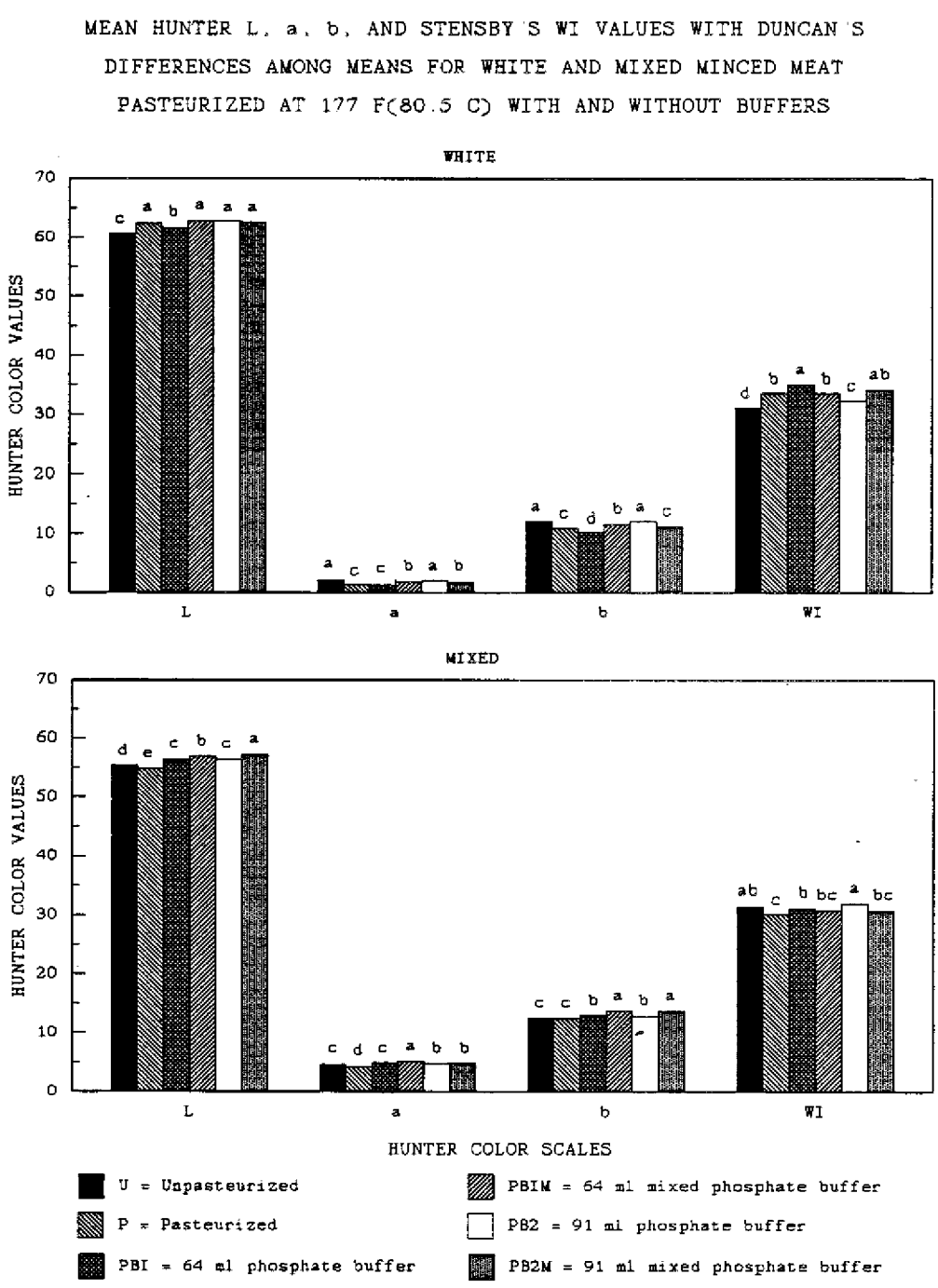


Figure 9. Color analyses of pasteurized white and mixed minced meat with and without buffers. Meat types with the same letter above mean bars for each color attribute are not different ($p < 0.05$).

Frozen Storage In Polyethylene Tubes

Mixed minced and minced claw meat pasteurized at 182°F (83.3°C) and stored at less than -4°F (-20°C) exhibited no consistent statistically significant differences with time for the following parameters during ten months of frozen storage: (1) bacterial levels, (2) proximate composition, (3) bluing, (4) wet-to-dry appearance, (5) ammonia odor, (6) cooked-crab odor, (7) cereal odor, (8) perceived moistness, (9) fibrousness, (10) adhesiveness, (11) chewiness, (12) particle size, (13) cooked-crab taste, (14) astringent taste, or (15) ammonia concentration.

Figure 10 shows Hunter L, a, and b colors and Stensby Whiteness Index values for mixed minced meat and minced claw meat stored at -4°F (-20°C) following pasteurization at 182°F (83.3°C). Figures 11 and 12 show putrid and TMA odor and sour, rancid, freezer-burn, and old-seafood flavors, respectively. Each parameter had consistent statistically significant changes with month of frozen storage for mixed minced and minced claw meat ($p < 0.05$). Table 1 presents Pearson Correlation Coefficients with measured parameters versus months of storage for minced claw and mixed minced meat, respectively.

Both minced claw and mixed minced meat darkened over ten months of frozen storage as indicated by decreasing Hunter L values. Significant and relatively high correlation coefficients were determined among storage month and L and WI values for minced claw meat ($p < 0.05$) (Table 1). The Hunter L value for minced claw meat at month ten was less than all other L values ($p < 0.05$). Zero time and months one and two for mixed minced meat and month one for minced claw meat had definitely higher L values than other storage months ($p < 0.05$). WI levels for minced claw at zero time and month one were distinctly higher than all other months ($p < 0.05$). WI values decreased significantly at two and three months of storage. Stored claw meat had definitely lower WI ratings in the remaining months of storage ($p < 0.05$) (Figure 10, Table 1). Hunter a or redness increased

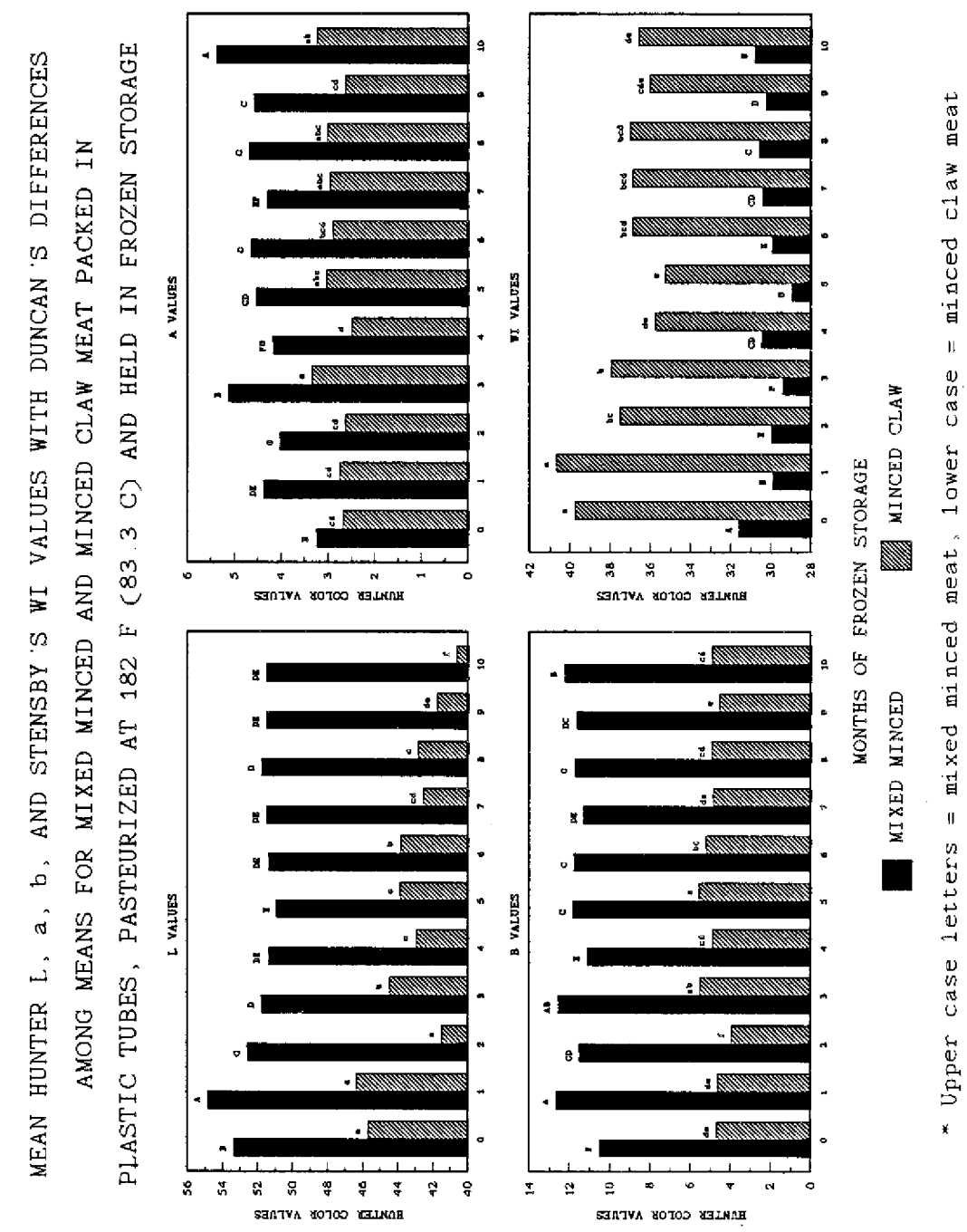


Figure 10. Color analyses of mixed and claw minced meat pasteurized in plastic tubes for 10 months frozen storage. Color with the same letter above mean bars are not different ($p < 0.05$).

Table 1. Pearson correlation coefficients of measured parameters during 10 months of frozen storage for minced claw and mixed minced meat held in ring sealed low density polyethylene tubes following pasteurization at 182°F. Coefficients statistically significant at the 0.05 level are marked with an "*".

PARAMETER	MINCED CLAW MEAT	MIXED MINCED MEAT
Aerobic Plate Counts	.34167	.20143
% Moisture	-.16755	-.32687
% Ash	.51435*	-.37642
% Protein	.36895	.15486
% Fat	.10923	.2131
% Moisture Free Ash	.34753	-.33826
% Moisture Free Protein	.14887	-.10075
% Moisture Free Fat	.09119	.11696
L	-.72702*	-.6723*
a	.30249	.65512*
b	.1786	.16266
WI	-.71097*	.03616
Wet/Dry Appearance	-.35982*	-.35535*
Ammonia Odor	.46006*	.35127*
Cooked Crab Odor	-.53086*	-.21895
Putrid Odor	.59845*	.56787*
TMA Odor	.52751*	.59311*
Cereal Odor	-.46448*	-.5543*
Moistness	-.12734	-.31579*
Fibrousness	-.09042	-.32977*
Adhesiveness	-.20215	-.10123
Chewiness	.02887	-.0405
Particle Size	-.05169	-.2822*
Cooked Crab Taste	-.41355*	-.42984*
Astringent Taste	-.08051	.0142
Sour Taste	.40623*	.31069*
Rancid Taste	.58961*	.63866*
Freezer Burn Taste	.53442*	.46551*
Old Seafood Taste	.61024*	.57491*
Ammonia	-.44303*	-.10662

with time for mixed minced meat samples during frozen storage in plastic tubes, with a correlation coefficient of 0.655 (Table 1, Figure 10). Hunter b, or bluing, levels showed no consistent trends for minced claw or mixed minced meat (Figure 10).

Putrid odors increased with time for both minced claw and mixed minced meat during ten months of frozen storage in polyethylene tubes. Putrid odors were significantly greater for both meats at ten months of storage than all other sampled months ($p < 0.05$) (Figure 11). Correlation coefficients for putrid odor and storage month were significant at the 0.05 level with correlation values greater than 0.5 (Table 1). Trimethylamine (TMA) odors followed a pattern similar to putrid odors with month ten exhibiting the strongest odors and similar correlation coefficients (Figure 11, Table 1).

Sour taste was greater at month ten for mixed claw meat and definitely greater at month ten than months zero through seven for mixed minced meat ($p < 0.05$) (Figure 12). Correlation coefficients were statistically significant but low for both meats (Table 1). Rancid taste results were similar. Minced claw meat was notably more rancid by month ten than monitored samples from zero time through seven months of frozen storage ($p < 0.05$). Mixed minced meat was definitely more rancid by month ten than all preceding months ($p < 0.05$). Rancid taste correlation coefficients with time for both meats were greater than 0.5 ($p < 0.05$) (Table 1). Following ten months of storage, mixed minced meat was definitely more rancid than minced claw meat ($p < 0.05$), although no significant differences were determined between the two meats for the first nine months of storage (Figure 12). Freezer-burn taste was notably greater at month ten than all other monitored storage times for both mixed minced meat and minced claw meat ($p < 0.05$) (Figure 12). Correlation coefficients were statistically significant with storage month for both meats, but only exceeded 0.5 for minced claw (Table 1). Minced claw old-seafood flavor was significantly stronger in months nine and ten than all preceding months ($p < 0.05$) (Figure 12). Old-seafood flavor for mixed minced meat was definitely greater by month ten than all other storage

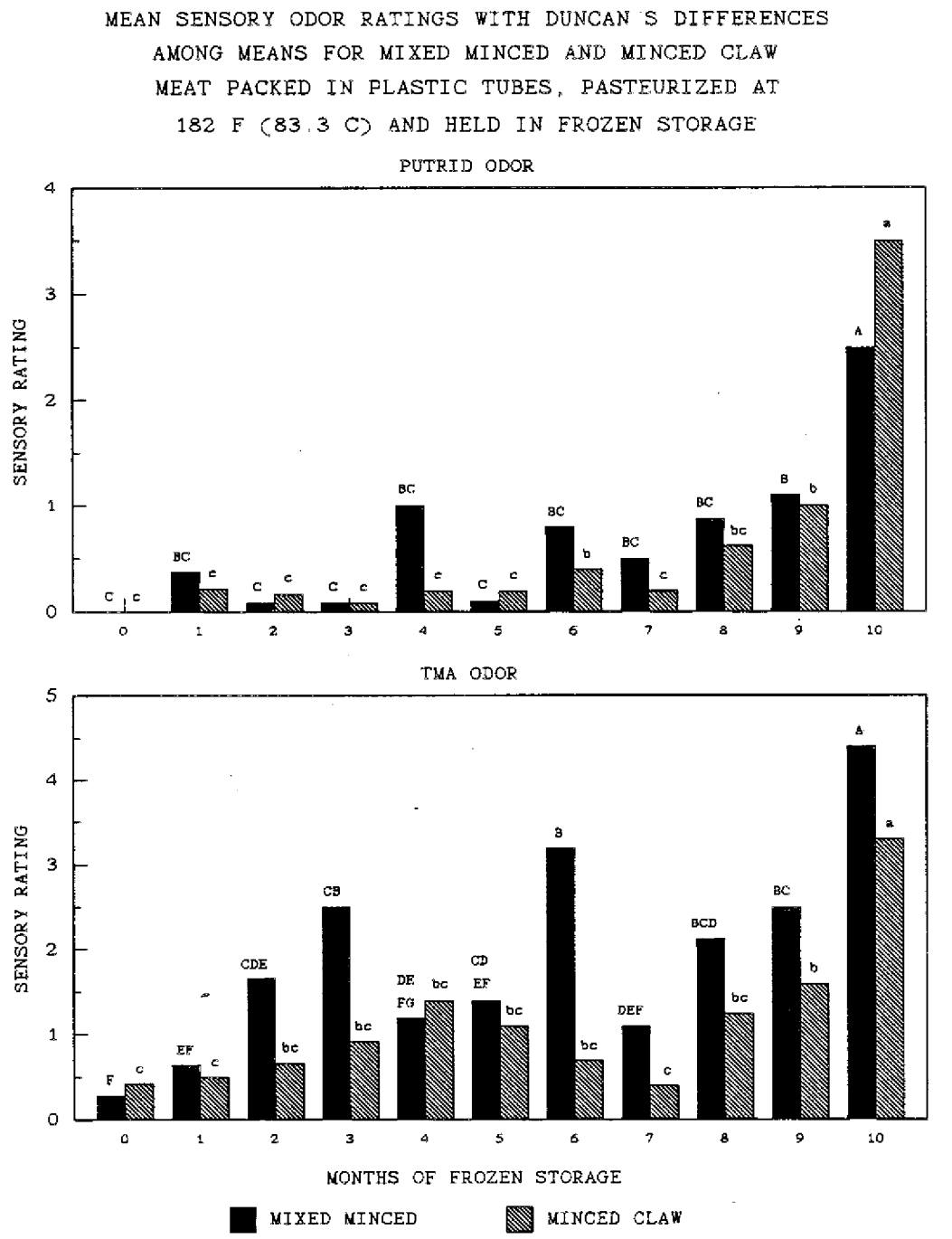


Figure 11. Odor analyses of mixed and claw minced meat pasteurized in plastic tubes and held for 10 months frozen storage. Odors with the same letter above bars are not different ($p < 0.05$).

months ($p < 0.05$) (Figure 12). Old-seafood taste correlation coefficients were statistically significant at the 0.05 level for both treatments, with coefficients exceeding 0.5 (Table 1).

Both minced claw meat and mixed minced meat pasteurized at 182°F (83.3°F) and packaged in plastic tubes deteriorated during frozen storage. There was a marked quality loss by month ten. Meats darkened and developed "off" odors and "off" flavors. Storage time correlated well with L values, putrid odors, TMA odors, rancid flavors, and old-seafood flavors for both meat types. Mixed minced meat was significantly more rancid at the end of ten months than minced claw meat.

Frozen Storage In Aluminum Cans

Buffered and unbuffered mixed minced meat pasteurized at 177°F (80.5°C) and stored in eight-ounce cans at less than -4°F (-20°C) exhibited no consistent statistically significant differences with time for the following parameters during eleven months of frozen storage: (1) bacterial levels, (2) % protein, (3) % fat, (4) % moisture-free protein, (5) sensory odors, (6) fibrousness, (7) adhesiveness, (8) chewiness, (9) particle size, (10) sensory tastes, and (11) ammonia concentrations.

Figure 13 shows Hunter L, a, b, and Stensby WI values for buffered and unbuffered mixed minced meat during eleven months of frozen storage. Buffered meat was treated with 2.2 oz (64 ml) of citric acid phosphate buffer. Meat and buffer were well mixed prior to sealing. Pearson correlation coefficients for measured parameters versus months of storage for unbuffered and buffered meat are presented in Table 2.

Hunter L values decreased with time for both unbuffered and buffered minced meats with correlation coefficients of -0.771 and -0.702, respectively (Table 2). Buffered meat showed no decrease in L values for the first four months of storage

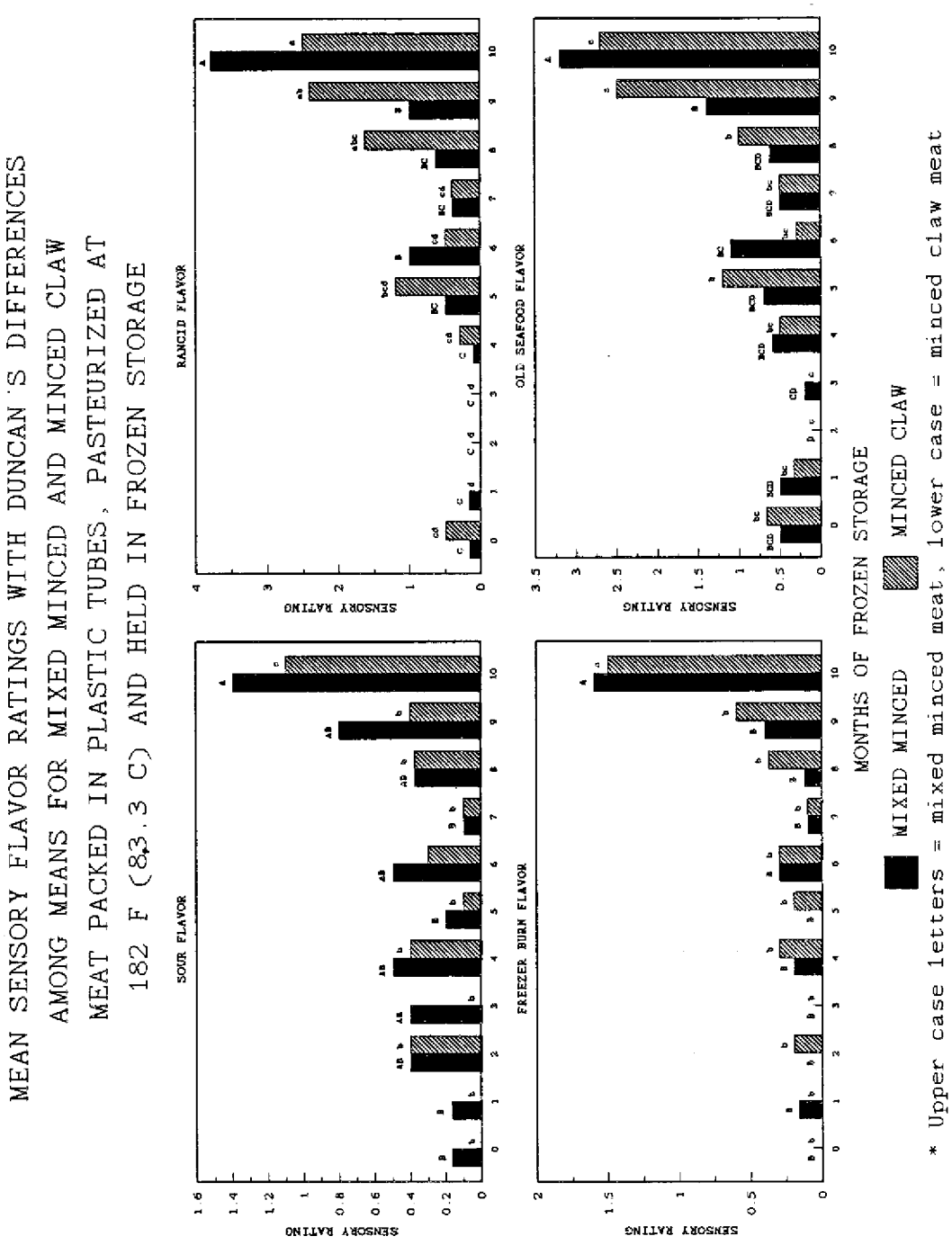


Figure 12. Flavor analyses of mixed and claw minced meat pasteurized in plastic tubes and held for 10 months in frozen storage. Flavors with the same letter above mean bars are not different ($p < 0.05$).

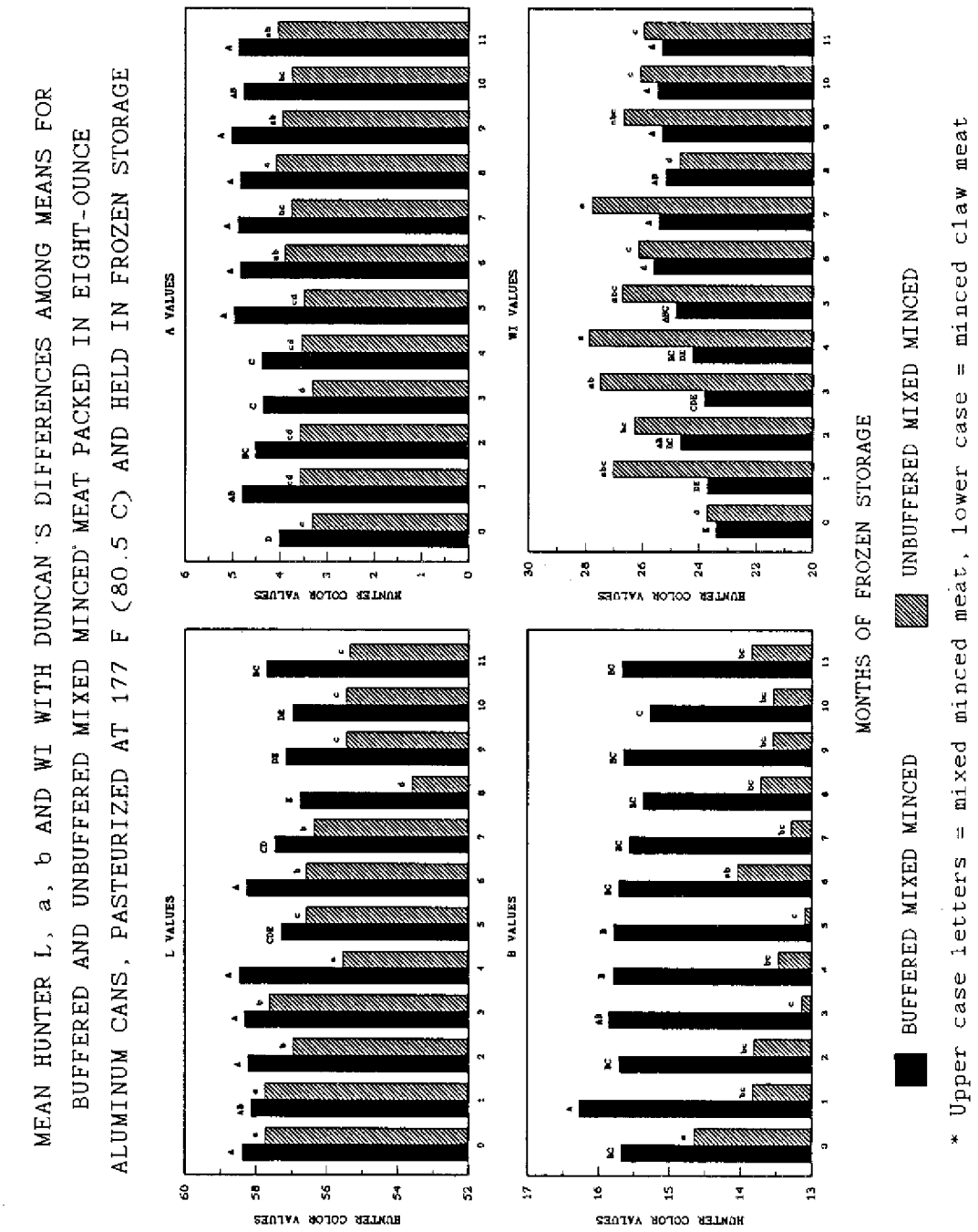


Figure 13. Color analyses of buffered and unbuffered mixed minced meat pasteurized in aluminum cans and held for ten months in frozen storage. Colors with same letter above mean bars are not different ($p < 0.05$).

Table 2. Pearson correlation coefficients of measured parameters during 11 months of frozen storage for unbuffered and buffered mixed minced meat held in eight-ounce aluminum cans following pasteurization at 177°F. Coefficients statistically significant at the 0.05 level are marked with an "*."

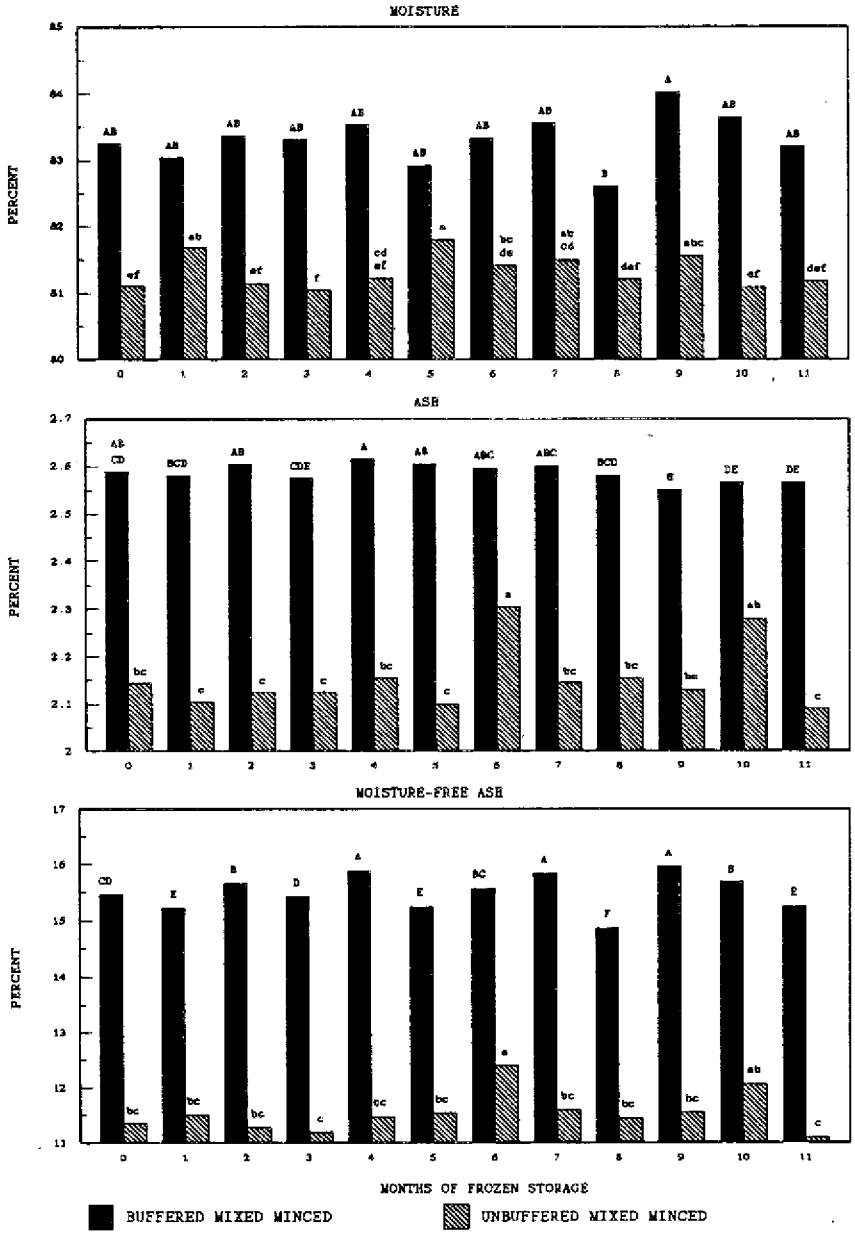
PARAMETER	UNBUFFERED	BUFFERED
Aerobic Plate Counts	-.19958	-.0905
% Moisture	-.01774	.14754
% Ash	.2047	-.46877*
% Protein	.21992	.03329
% Fat	.44304*	-.02108
% Moisture Free Ash	.19065	.05791
% Moisture Free Protein	.19344	.10491
% Moisture Free Fat	.49027*	.07001
L	-.77091*	-.70168*
a	.75941*	.65807*
b	-.25925	-.54876*
WI	.03461	.79262*
Wet/Dry Appearance	.04375	.47635*
Ammonia Odor	-.17069	.04188
Cooked Crab Odor	-.11161	.16179
Putrid Odor	-.13494	-.1925
TMA Odor	-.09777	.03009
Cereal Odor	.27401*	.30334*
Moistness	.24556	.45368*
Fibrousness	.48871*	.41844*
Adhesiveness	.44562*	.1472
Chewiness	.43278*	.39421*
Particle Size	.32362*	.32871*
Cooked Crab Taste	.05571	-.12844*
Astringent Taste	-.20621	-.28888
Sour Taste	-.11281	-.05397
Rancid Taste	-.16022	-.00881
Freezer Burn Taste	-.03899	.14156
Old Seafood Taste	.11555	.10506

($p < 0.05$) (Figure 13). Unbuffered meat showed no reduction in Hunter L or whiteness through the first month of storage ($p < 0.05$). There were no other clear divisions in whiteness during frozen storage. Buffered meat rated higher L values than unbuffered meat for all monitored months and was significantly greater than unbuffered meat in all but the following months; 1, 6, 7, and 9 ($p < 0.05$). Whiteness index correlated well with storage month for buffered meat, but was not statistically significant for unbuffered meat ($p < 0.05$)(Table 2). WI increased with time for buffered meat and was definitely greater than the WI of unbuffered meat in the eighth month of storage ($p < 0.05$) (Figure 13). Hunter a values increased during frozen storage of both unbuffered and buffered meats ($p < 0.05$). Correlation coefficients were 0.759 and 0.658, respectively (Table 2). No specific breakpoints in Hunter a values were determined for either mince over eleven months of frozen storage (Figure 13). Throughout the storage test buffered mixed minced meat had notably higher Hunter a value ratings, or increased redness, when compared to unbuffered meat ($p < 0.05$). Hunter b values determined for unbuffered meat definitely decreased, indicating increased bluing with storage time ($p < 0.05$). The correlation coefficient with time was -0.549. Buffered meat showed no distinct correlation with time (Table 2). Unbuffered Hunter b values were significantly less than values determined for buffered meats through eleven months of storage, indicating greater bluing in unbuffered meats ($p < 0.05$) (Figure 13).

Figure 14 presents mean proximate composition data for unbuffered and buffered mixed minced meat. No specific patterns with time were determined, however percent moisture content of buffered meat was significantly greater than that of unbuffered meat throughout the storage study ($p < 0.05$) (Figure 14, Table 2). Similar results were determined for ash and moisture free ash contents (Figure 14, Table 2). Higher moisture and salt contents in buffered meat were expected because of water and salts added to the buffer.

Sensory analyses determined few changes with time for buffered or unbuffered mixed minced meat held in eight-ounce aluminum cans. No significant

MEAN PROXIMATE ANALYSES WITH DUNCAN'S DIFFERENCES AMONG MEANS FOR BUFFERED AND UNBUFFERED MIXED MINCED MEAT PACKED IN EIGHT-OUNCE ALUMINUM CANS, PASTEURIZED AT 177 F (80 5 C) AND HELD IN FROZEN STORAGE



* Upper case letters = mixed minced meat, lower case = minced claw meat

Figure 14. Moisture, ash, and moisture-free ash analyses of buffered and unbuffered mixed minced meat pasteurized in aluminum cans and held for ten months in frozen storage. Proximates with same letter above bars are not different ($p < 0.05$).

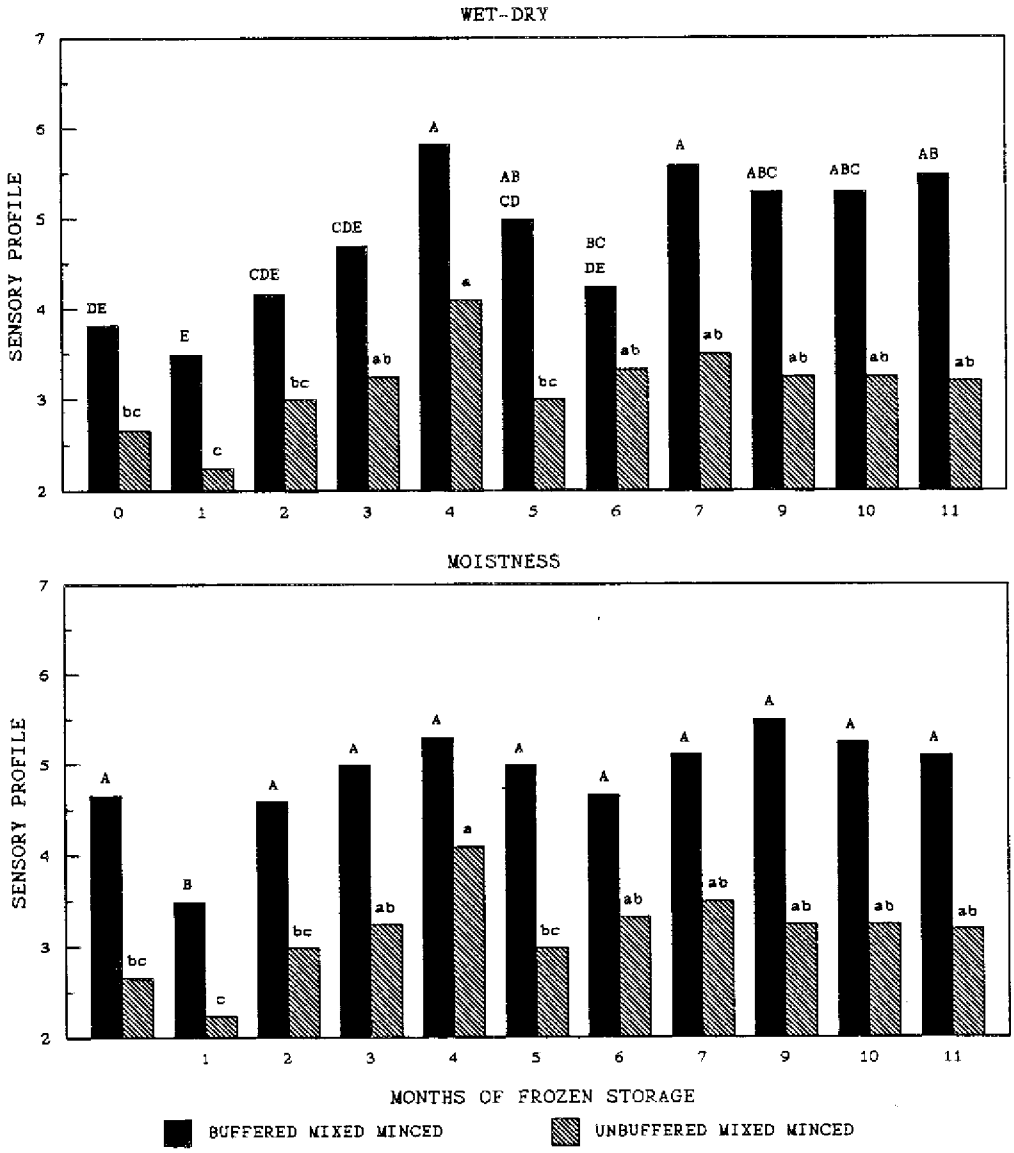
correlation coefficients exceeded 0.5 (Table 2) and no consistent changes with storage month were determined. However, wet-dry and moistness data in Figure 15 show distinct differences between buffered and unbuffered meat ($p < 0.05$). Buffered meat rated higher wet-dry values on all occasions with greater wetness in months two through eleven ($p < 0.05$). Results of moistness analyses were similar with buffered meat greater than unbuffered meat during all sampling months and significantly so on all but the first month of storage ($p < 0.05$) (Figure 15).

Mixed minced meat treated with 2.2 oz (64 ml) of citric acid phosphate buffer prior to pasteurization at 177°F (80.5°C) maintained better color than unbuffered meat during eleven months of frozen storage. Off-odor and off-flavor development were not as pronounced in aluminum cans as was previously noted for low-density polyethylene tubes. Low-density polyethylene has an oxygen permeability of 7750 $cm^3/m^3/25.4$ micron thickness/24hr/atm at 25°C (Sacharow and Griffin, 1980). High oxygen permeability of low-density polyethylene tubes is the most probable explanation for development of putrid and TMA odors, and sour, rancid, freezer-burn, and old-seafood tastes following ten months of frozen storage. Aluminum barrier cans did not exhibit the same characteristics.

Refrigerated Storage In Aluminum Cans

Buffered and unbuffered mixed minced meat pasteurized at 177°F (80.5°C) and stored in aluminum cans at less than 35°F (<1.7°C) showed no consistent statistically significant differences with time for the following parameters during thirteen months of refrigerated storage: (1) bacterial levels, (2) % protein, (3) % fat, (4) % ash, (5) Hunter L, (6) Hunter a, and (7) Hunter b. Cans used in the study were from the same lot that the cooperating crab processor determined to be defective. The formed aluminum cans were stretched too thin along portions of the body, resulting in intermittent and random leaks with subsequent bacterial spoilage. Sensory characteristics of the canned meats were not evaluated because of intermittent spoilage.

MEAN SENSORY ANALYSES WITH DUNCAN S DIFFERENCES AMONG MEANS FOR BUFFERED AND UNBUFFERED MIXED MINCED MEAT PACKED IN EIGHT-OUNCE ALUMINIUM CANS, PASTEURIZED AT 177 F (80.5 C) AND HELD IN FROZEN STORAGE



* Upper case letters = mixed minced meat, lower case = minced claw meat

Figure 15. Wet-dry and moistness sensory analyses of buffered and unbuffered mixed minced meat pasteurized in aluminum cans and held for ten months in frozen storage. Values with the same letter are not different ($p < 0.05$).

Figure 16 shows plate count analyses of minced meat packaged in 8-ounce aluminum cans during 13 months of refrigerated storage. Plate counts exceeded 3,000 CFU/g, the maximum limit for pasteurized crab meat set by the Tri-state Seafood Committee (1971), on six occasions. Spoilage patterns were not consistent with time, however unbuffered meat plate counts exceeded the standard on five of six occasions and were significantly greater than buffered plate counts on each of those occasions ($p < 0.05$).

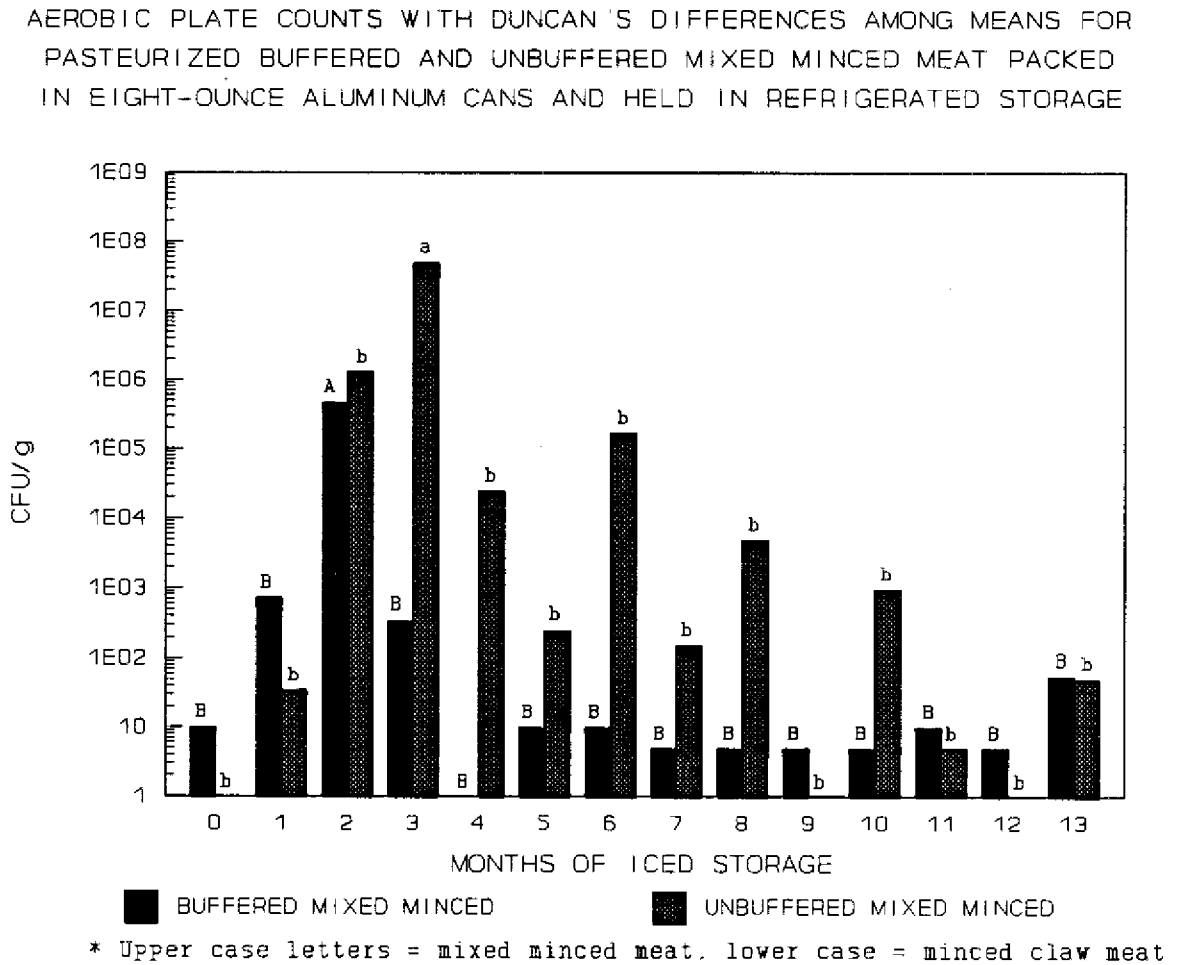


Figure 16. Log of aerobic plate counts for buffered and unbuffered mixed minced meat pasteurized in aluminum cans during thirteen months of refrigerated storage. Meats with the same letter above mean bars are not different ($p < 0.05$).

Figure 17 presents Hunter L, a, b, and Stensby WI values for pasteurized mixed minced meat and buffered mixed minced meat. Hunter L or whiteness values for buffered meat were greater than the L values of unbuffered meats for all monitored months and statistically significantly greater than unbuffered meats in 10 of 13 months ($p < 0.05$). Hunter a or meat redness showed no consistent differences between treatments. Buffered minced meat rated higher Hunter b values or less bluing than unbuffered meat for all monitored months and was significantly less blue ($p < 0.05$) in months 0, 1, 3 ,4 ,5 ,6, 11, and 13. Stensby's WI showed buffered minced meat to be whiter than unbuffered meat during all but the second and fourth months of refrigerated storage.

Figure 18 shows the proximate composition of buffered and unbuffered minced meat during thirteen months of refrigerated storage. Increased salt and moisture contents of the buffered meats confirm the addition of water and salts to the buffered meat samples. Reduced protein and fat values in the buffered meats also reflect the addition of water to the meats. Figure 19 presents moisture free proximate analyses for buffered and unbuffered meats. Moisture free ash levels determined for buffered meats were greater than levels determined for unbuffered meat ($p < 0.05$), revealing increased salt content from the buffer. Unbuffered meat had greater moisture-free protein content in 12 of 13 months, but levels were statistically significant in only 4 of the storage months ($p < 0.05$).

Table 3 shows Pearson correlation coefficients for monitored parameters over 13 months of storage for unbuffered and buffered meats. Two parameters received correlation coefficient ratings >0.5 that were statistically significant at the 0.05 level. Unbuffered meat WI values and moisture free protein levels for buffered meat met both criteria and increased with storage month. Buffered minced meat rated higher Hunter b values or less bluing than unbuffered meat for all monitored months. Stensby's WI showed buffered minced meat to be whiter than unbuffered meat during storage. Except for intermittent spoilage which was attributed to faulty cans, pasteurized minced meat maintained acceptable microbiological quality for thirteen months of storage at less than 35°F (<1.7°C).

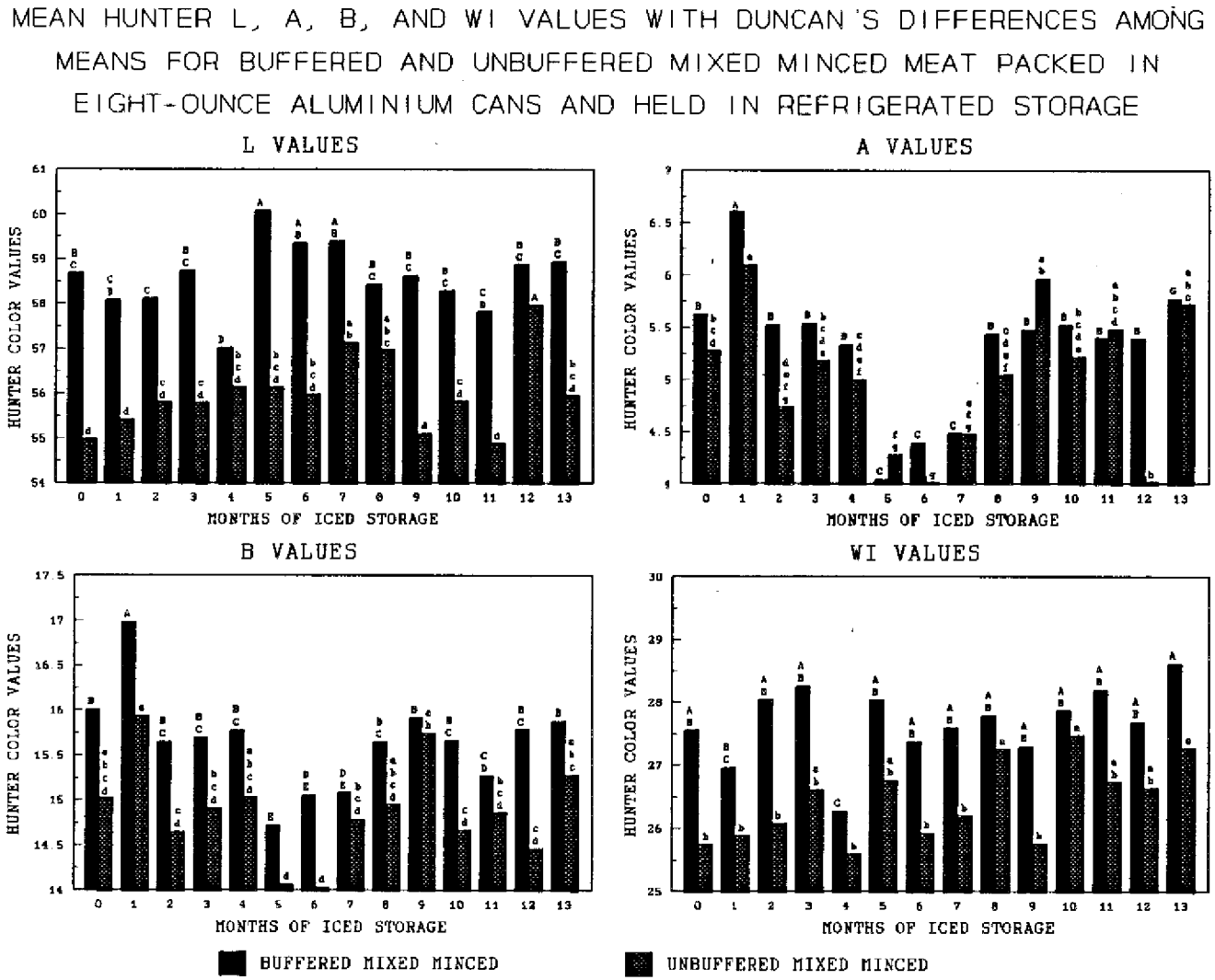


Figure 17. Color analyses for buffered and unbuffered mixed minced meat pasteurized in aluminum cans during thirteen months of refrigerated storage. Colors with same letter above mean bars are not different ($p < 0.05$).

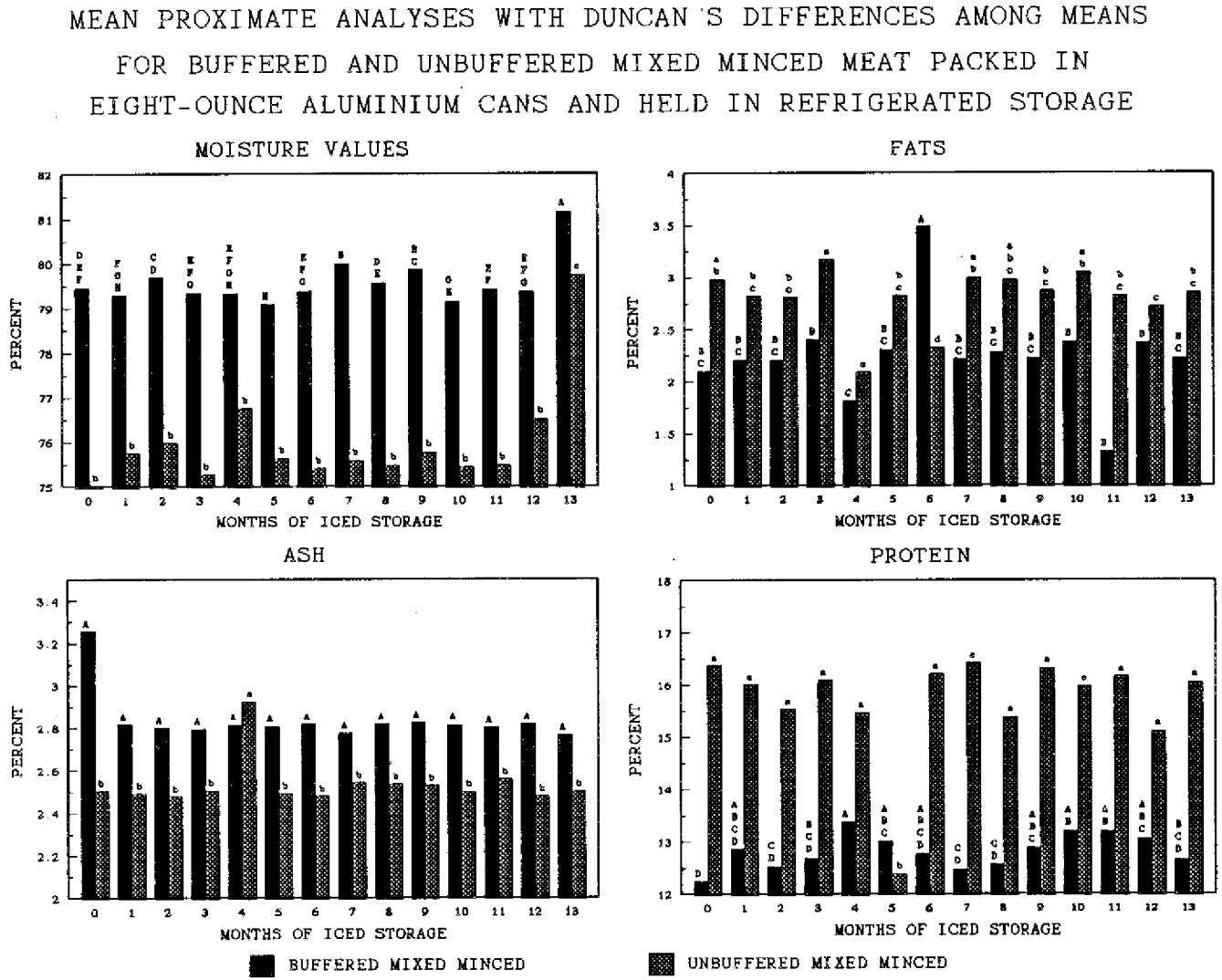


Figure 18. Proximate analyses for buffered and unbuffered mixed minced meat pasteurized in aluminum cans during thirteen months of refrigerated storage. Values with the same letter above mean bars are not different ($p < 0.05$).

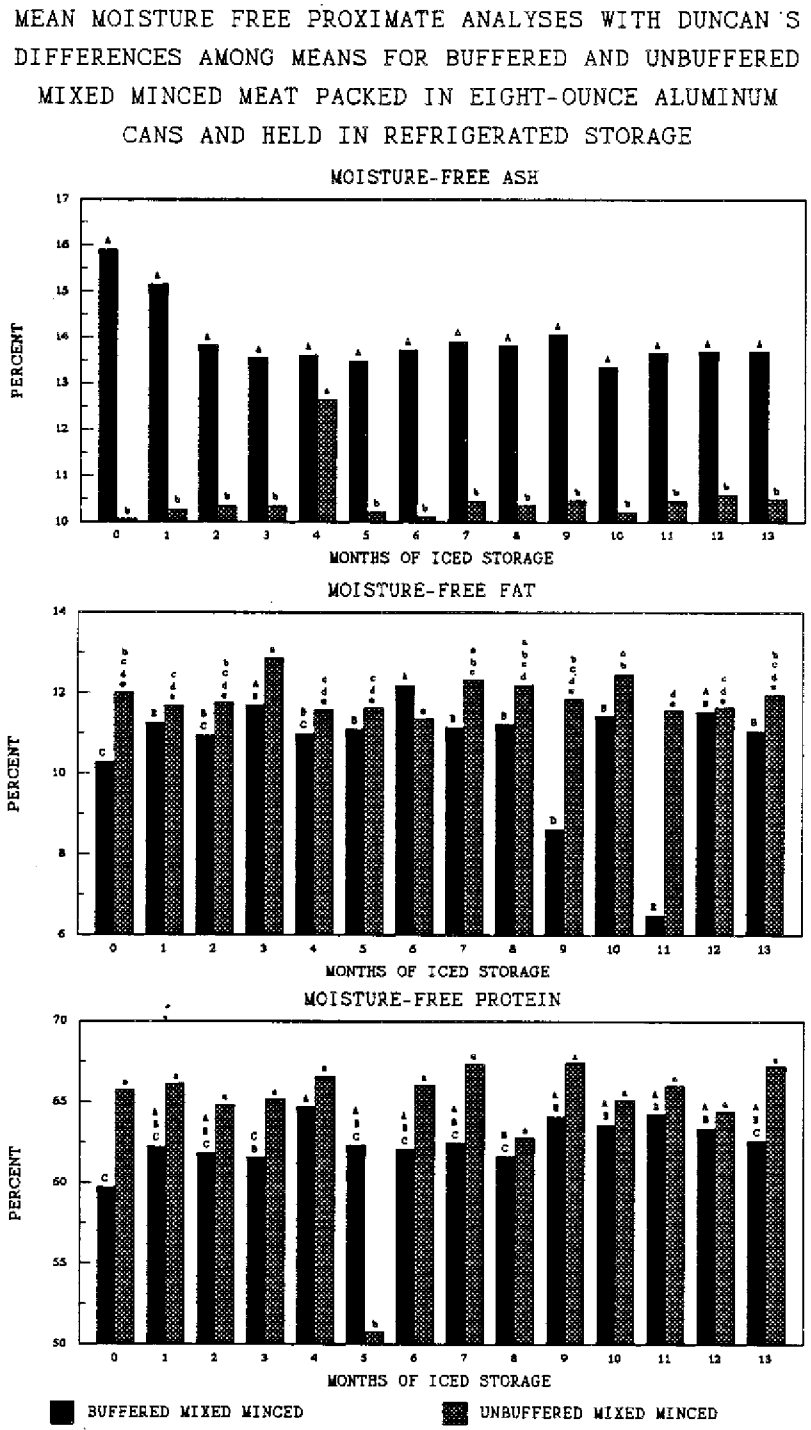


Figure 19. Moisture-free analyses for buffered and unbuffered mixed minced meat pasteurized in aluminum cans during thirteen months of refrigerated storage. Values with same letter above mean bars are not different ($p < 0.05$).

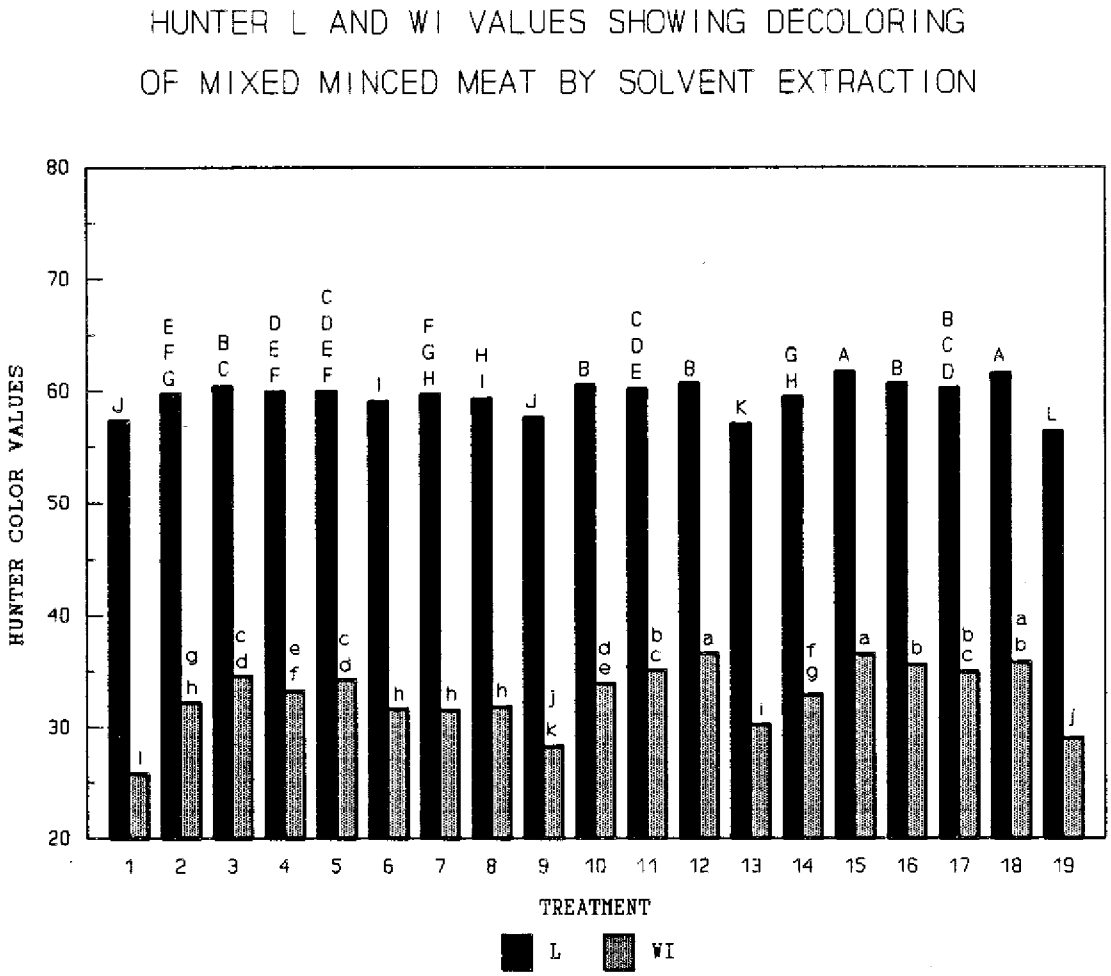
Table 3. Pearson correlation coefficients of measured parameters during 13 months of refrigerated storage for unbuffered and buffered mixed minced meat held in eight-ounce aluminum cans following pasteurization at 177°F. Coefficients statistically significant at the 0.05 level are marked with an "*."

PARAMETERS	UNBUFFERED	BUFFERED
Aerobic Plate Counts	-23804	-.31949
% Moisture	.40521*	.40943*
% Ash	-.10076	-.35238
% Protein	.03016	*.38969
% Fat	.08703	-.10115
% Moisture Free Ash	-.04654	-.41953
% Moisture Free Protein	.08954	.54259*
% Moisture Free Fat	-.01831	-.25374
L	.29602	.06568
a	-.03067	-.10274
b	-.08734	-.24002
WI	.55555*	.26134

Color Extraction

Figures 20, 21, and 22 show Hunter L, a, b, Stensby WI index, and sensory panel color results for solvent extracted mixed minced meat. All washes except cold ethanol, bicarbonate/ethanol, and hot ethanol brightened the product in terms of Hunter L values (Figure 20)($p < 0.05$). The two most successful treatments to improve Hunter L lightness were bicarbonate/water/water and the three water washes. Stensby's whiteness index showed that the bicarbonate/SPD/sodium chloride and the three water washes produced the whitest products. The untreated control sample had the lowest blue rating on the Hunter b scale (Figure 21). Higher b values indicated increasing yellow color and decreasing blue color. Bicarbonate/SPD/NaCl washes produced the bluest samples. Mixed minced control and meat treated with cold ethanol had the highest Hunter a rating, ranking those products as the most red. Hunter a ratings showed

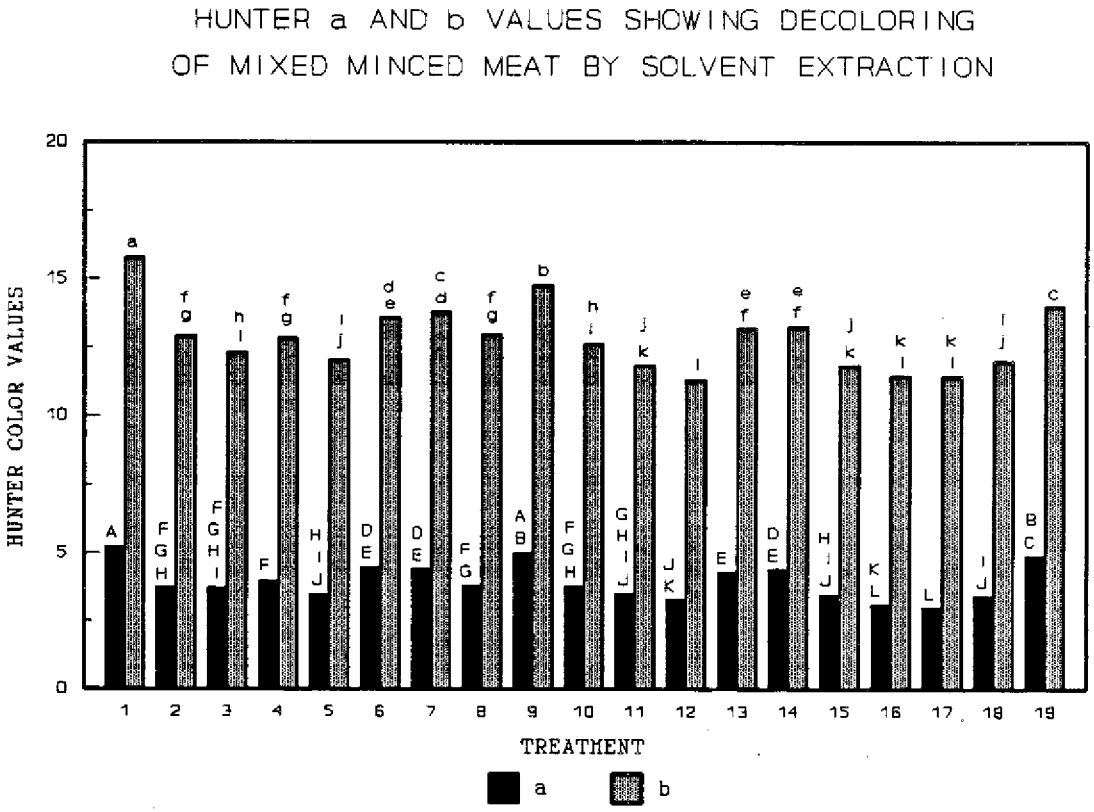
bicarbonate/STP/NaCl/water and bicarbonate/STP/NaCl/water treated mixed minced meat to be the greenest samples (Figure 21). However, a five-member sensory panel determined no statistically significant differences among sample colors for the 19 treatments (Figure 22).



* Upper case letters = mixed minced meat, lower case = minced claw meat

1 = Unwashed control
2 = Cold water
3 = 2x with cold water
4 = 0.5% Sodium bicarbonate
5 = Bicarbonate/water
6 = 0.05% sodium tripolyphosphate
7 = 0.05% sodium tripolyphosphate dibasic
8 = 0.3% sodium chloride
9 = Cold ethanol
10 = Bicarbonate/sodium chloride
11 = Bicarbonate/STP/sodium chloride
12 = Bicarbonate/SPD/sodium chloride
13 = Bicarbonate/ethanol
14 = Ethanol/water
15 = 3x with cold water
16 = Bicarbonate/STP/Nacl/water
17 = Bicarbonate/SPD/Nacl/water
18 = Bicarbonate/water/water
19 = Hot ethanol

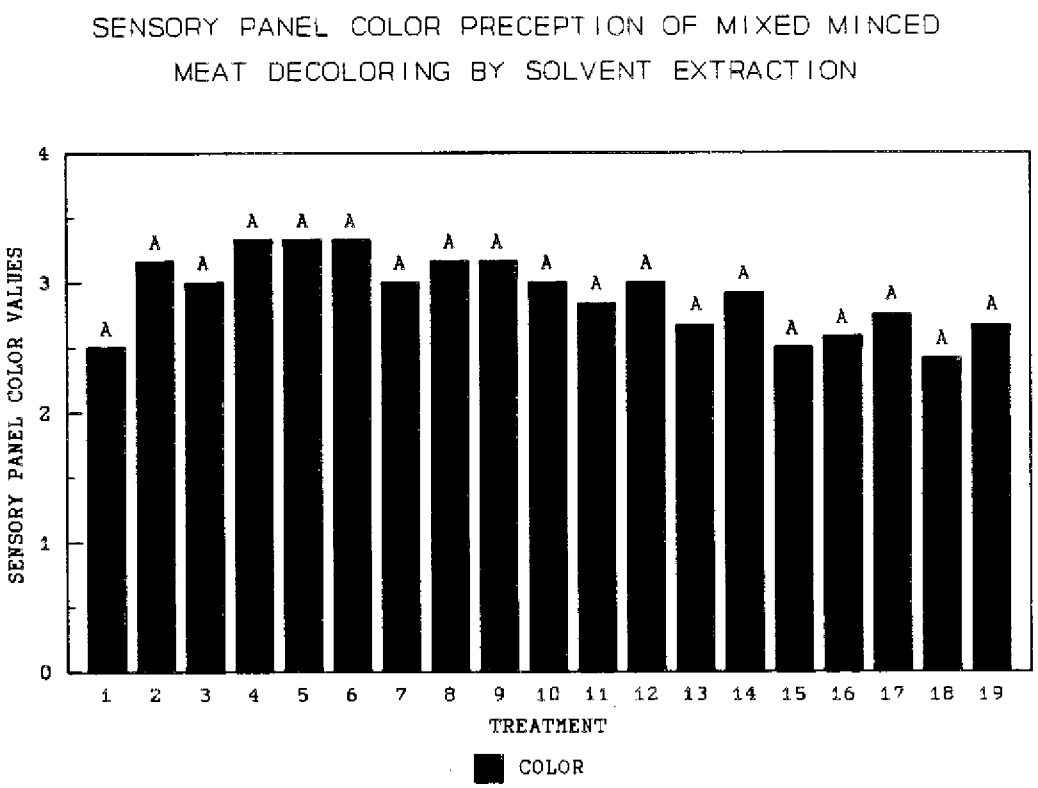
Figure 20. Hunter L and WI color changes in mixed minced meat following solvent extraction. Meat treatments with the same letter above mean bars are not different ($p < 0.05$).



* Upper case letters = mixed minced meat, lower case = minced claw meat

1 = Unwashed control
2 = Cold water
3 = 2x with cold water
4 = 0.5% Sodium bicarbonate
5 = Bicarbonate/water
6 = 0.05% sodium tripolyphosphate
7 = 0.05% sodium tripolyphosphate dibasic
8 = 0.3% sodium chloride
9 = Cold ethanol
10 = Bicarbonate/sodium chloride
11 = Bicarbonate/STP/sodium chloride
12 = Bicarbonate/SPD/sodium chloride
13 = Bicarbonate/ethanol
14 = Ethanol/water
15 = 3x with cold water
16 = Bicarbonate/STP/Nacl/water
17 = Bicarbonate/SPD/Nacl/water
18 = Bicarbonate/water/water
19 = Hot ethanol

Figure 21. Hunter a and b color changes in mixed minced meat following solvent extraction. Meat treatments with the same letter above mean bars are not different ($p < 0.05$).



* Upper case letters = mixed minced meat, lower case = minced claw meat

1 = Unwashed control
2 = Cold water
3 = 2x with cold water
4 = 0.5% Sodium bicarbonate
5 = Bicarbonate/water
6 = 0.05% sodium tripolyphosphate
7 = 0.05% sodium tripolyphosphate dibasic
8 = 0.3% sodium chloride
9 = Cold ethanol
10 = Bicarbonate/sodium chloride
11 = Bicarbonate/STP/sodium chloride
12 = Bicarbonate/SPD/sodium chloride
13 = Bicarbonate/ethanol
14 = Ethanol/water
15 = 3x with cold water
16 = Bicarbonate/STP/Nacl/water
17 = Bicarbonate/SPD/Nacl/water
18 = Bicarbonate/water/water
19 = Hot ethanol

Figure 22. Sensory panel hedonic evaluation of color changes in mixed minced meat following solvent extraction. Meat treatments with the same letter above mean bars are not different ($p < 0.05$).

CONCLUSIONS

Blue crab picking-room by-products were separated into four components prior to extraction with a Baader 694 machine. By-product types were: (1) "slabs," the portion of hand-picking by-product containing only white body meat; (2) mixed by-product that includes all picking-room by-products but claws; (3) separated legs; and (4) separated claws. Minced meat yields based on the weight of an uncooked green crab were: white meat, 3.18%; mixed minced meat, 13.89% (10.71% if slabs are separated); minced leg, 2.62%; and minced claw, 6.39%. Total recoverable minced meat is approximately 22% of an uncooked crab's weight. Yields based on cooked by-product type as the starting point were: 76.63%, 59.45%, 40.44%, and 38.07% for "slab," mixed, leg, and claw by-products, respectively.

Four meats with distinct chemical compositions, colors, flavors, and textures were extracted. Leg and mixed minced meat had the highest moisture contents. Ash contents were low, ranging from 1.57% for leg meat to 2.14% for mixed minced meat, indicating little shell contamination. Fat content was low, ranging from 0.12% to 1.73%. "Slabs" produced a dry, white, textured mince; mixed by-product a moist, golden-brown mince; legs a smooth, flavorful, dark-brown mince; and claws a highly-textured, less-flavored, chewy, brown mince.

Minced meat exhibited excessive microbial levels, ranging from 10^5 to 10^7 CFU/g. Growth at room temperature was rapid. Extraction of by-products within 1.5 hours of picking showed little increase in the microbial populations of mixed by-products. By-products should be extracted within 1.5 hours of picking or the by-products need to be iced or refrigerated to control microbial growth.

Reduced pasteurization temperatures improved the appearance of minced meat and effectively reduced microbial populations. Initial reduction of pasteurization temperatures from 186°F (85.5°C) to 182°F (83.3°C) ($F_{185}^{16} = 44$) improved the appearance of pasteurized meats. However, all minced meats darkened

following pasteurization at 182°F (83.3°C). Pasteurization of minced white meat and mixed minced meat at 177°F (80.5°C) (F_{185}^{16} = 38) significantly improved the appearance of pasteurized meats. Minced white meat and mixed minced meat blued less and mixed minced was definitely more white when pasteurized at 177°F (80.5°C). The addition of citric acid phosphate buffer to minced white and mixed minced meat prior to pasteurization at 177°F (80.5°C) produced product that was rated as more white, less green, and less blue than unbuffered meat. Pasteurization at 177°F (80.5°C) (F_{185}^{16} = 38) effectively reduced microbial levels.

Mixed minced meat and minced claw meat pasteurized at 182°F (83.3°C) to an F_{185}^{16} = 44 in 5 mil, low-density, ring-sealed, polyethylene tubes exhibited color and sensory deterioration during ten months of frozen storage at less than -4°F (-20°C). Meats darkened and turned more red with storage time as indicated by Hunter L and a values. Putrid and TMA odors and sour, rancid, freezer-burn, and old seafood tastes definitely increased by the tenth month of frozen storage for both minces. Mixed minced meat was more rancid than minced claw meat at the end of ten months frozen storage.

Mixed minced meat well mixed with 2.2 oz (64 ml) of citric acid phosphate buffer prior to pasteurization at 177°F (80.5°C) in eight-ounce aluminum cans (F_{185}^{16} = 38) maintained better color than unbuffered meat during eleven months of frozen storage at less than -4°F (-20°C) as indicated by Hunter L, a, b, and Stensby WI color values. Buffered meat had significantly greater moisture and ash contents. Sensory profiles showed buffered meat to be more moist and have a wetter appearance than unbuffered meat. Both buffered and unbuffered mixed minced meat stored in aluminum cans failed to produce "off" odors and flavors that developed during frozen storage of mixed minced meat and minced claw meat stored in low-density polyethylene tubes. Color changes in aluminum cans were also less pronounced. Oxygen permeability of the polyethylene tubes is the most probable explanation for development of "off" odors and flavors.

Crab processors extracting minced meat from picking room by-products for pasteurization and frozen storage should use oxygen barrier materials if anticipated frozen storage times exceed six to eight months. Oxygen barrier packaging, as indicated by our work with aluminum cans, permits effective frozen storage for at least eleven months. Minced meat color darkens with time, but low temperature pasteurization at 177°F (80.5°C) coupled with addition of citric acid phosphate buffer greatly reduces color deterioration during frozen storage.

Except for intermittent spoilage that was attributed to faulty cans, pasteurized minced meat maintained acceptable microbiological quality for thirteen months of refrigerated storage at less than 35°F (<1.7°C). Buffered minced meat displayed less bluing than unbuffered meat. Buffered minced meat was whiter than unbuffered meat. As with frozen minced meat, the addition of phosphate citric acid buffer significantly improved the appearance of pasteurized minced crab meat.

Solvent extraction of mixed minced meat did lighten the product as determined by the ACS Spectro Sensor. However, the sensory panel did not determine any significant color differences following 19 different treatments. Solvent extraction was not very effective in lightening the color of mixed minced meat.

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