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PACKAGING SYSTEMS FOR THE PROTECTION OF FRESH BEEF DURING SHIPMENT AND STORAGE

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Summary

Test shipments and storage trials involving 1225 beef quarters or wholesale cuts were conducted to investigate the effects of protective packaging systems on certain wholesale and retail cut characteristics. Polyethylene bags and polyvinyl chloride film reduced intransit shrinkage and improved muscle color and subcutaneous fat appearance in comparison to unprotected cuts during test shipments. The use of chloride films for storage of beef cuts for 5 days decreased shrinkage yet had no effect on bacterial counts or incidence of off-odors. Storage intervals of 8 days or longer in chloride film resulted in increased bacterial counts and undesirable odor scores and thus would not be feasible. The success of vacuum packaging as a means of preservation for beef cuts depends greatly upon the degree of vacuumization achieved. Steaks from vacuum packaged ribs had 1 day of additional caselife in comparison to ribs wrapped in polyvinyl chloride film (storage interval of 11 days) and were more acceptable to consumers in appearance and palatability than ribs chilled with carbon dioxide (storage interval of 17 days). Vacuum packaged rounds were more desirable in muscle and fat appearance, had lower bacterial counts, less off-odor, required much less trimming prior to cutting and produced retail cuts with greater expected caselife than rounds which were chilled with carbon dioxide pellets.

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Introduction

In the United States, fresh beef is shipped directly from packers to retail stores or to central distribution warehouses with subsequent transport to retail stores. Weatherly, Earle and Brown (1968) estimated that fresh beef typically moves through a 9-day cycle from packer to retail sale. Since 4 days are required for transportation (Weatherly et al., 1968) and retail cuts have an expected caselife of 3 days (Leach, 1968) beef is often stored for 2 to 4 days at the store prior to cutting and retail display. The recent trend in the U.S. toward relocation of slaughter plants closer to sources of cattle supply has increased the distance between packers and retail stores and emphasized the need (U.S.D.A., 1966) for an inexpensive packaging material to protect beef from dehydration and discoloration during distribution. A second trend involves a change from distribution of intact quarters to direct delivery of prefabricated and boxed primal or subprimal cuts (Kearney, 1969). The experiments described here investigated the effects of protective packaging systems on shrinkage, bacterial counts and appearance of quarters or wholesale cuts and the caselife and palatability of subsequent retail cuts.

Experimental Procedure

The essential elements of the experimental design for test shipments and storage trials are presented below or are included in the tabular material.

Test Shipments. Five test shipments were conducted in cooperation with industry to study the effects of protective packaging materials on beef quarters and primal cuts. The quarters and primal cuts were either not wrapped (unprotected) or they were protected by paper bags, polyethylene bags or polyvinyl chloride film. Individual weights were obtained for quarters and/or

primal cuts immediately prior to packaging and at load destinations. In test shipments 2, 3 and 5 the exposed muscle surfaces of representative cuts were scored at points of origin and destination by use of a 9-point scale (Table 1). Quarters and primal cuts in test shipments 2, 3, 4 and 5 were scored before and after shipment for appearance of the subcutaneous fat cover using a 6-point scale (Table 1). Loading patterns and product density during shipment were noted and temperature fluctuations during loading, transit and unloading were monitored.

Storage Trials. Ten trials, involving 297 quarters or wholesale cuts, were conducted to compare packaging systems for use during storage periods of 5 to 13 days. Quarters and wholesale cuts obtained from the matched right and left sides of 37 carcasses were randomly assigned to unprotected storage. The counterpart quarter or cut (from the opposite side) was assigned to one of four packaging treatments (paper bag, polyethylene bag, chloride bag or vacuum package). Each quarter or cut was weighed immediately prior to and following storage to measure shrinkage loss. Upon termination of the storage trial, each quarter or cut was assigned an odor score by a trained 3-member panel by use of a 4-point scale (Table 2) and a bacterial sample was collected by swabbing an area of the subcutaneous fat cover. The bacterial sampling procedure involved the use of a sterile cotton swab, phosphate buffer and a 1 cm^2 sterile aluminum template. Appropriate dilutions were transferred to petri dishes containing tryptone glucose yeast agar and the plates were incubated at 3°C for 7 days.

In storage trial 11, primal cuts were obtained from both sides of 18 beef carcasses (2 days postmortem). Primal cuts from the right sides were vacuum packaged; those from the left sides were wrapped in polyvinyl chloride film (PVC). All primal cuts were stored on metal tables in a 36°F cooler for 11 days. Primal cuts were evaluated for muscle color, fat appearance, odor and completeness of vacuum by use of 9, 6, 4 and 4-point scales illustrated

in Tables 1, 1, 3 and 4, respectively. Bacterial samples were collected from areas of the subcutaneous fat cover prior to and following storage. Total psychrotrophic counts were determined after incubation at 5°C for 10 days on standard plate count agar. Individual steaks were obtained from each wholesale rib, trimmed, placed in styrofoam trays, wrapped in oxygen permeable film and displayed at 35°F for 5 days. The steaks were evaluated daily for muscle color, hedonic desirability, peripheral discoloration and surface discoloration by use of 9, 8, 5 and 7-point scales (Table 3) and on the final day of display for odor by use of a 4-point scale (Table 3).

Test Shipment and Storage of Boxed Beef. Twenty ribs and 20 rounds were vacuum packaged (VP) and the counterpart cuts from the opposite side of each carcass were placed in polyethylene bags with 1 kg of carbon dioxide (CO_2) pellets. The cuts were placed in cardboard boxes (1 round per box; 2 ribs per box), shipped 1287 km, unloaded and stored for 3 days in a 1°C cooler at a distribution center. The boxed cuts were subsequently loaded, shipped 322 km, unloaded in a 2°C cooler for 3 or 10 days. Ten each of the rounds and ribs from VP and CO_2 treatments were removed from storage and evaluated at 10 and 17 days postmortem. Upon completion of the designated storage interval the wholesale cuts were scored for propriety of vacuum, subcutaneous fat appearance, muscle color, muscle surface discoloration, overall desirability and odor by use of 4, 6, 9, 7, 8 and 4-point scales (Tables 4 and 5). Each wholesale cut was trimmed to remove discolored or spoiled portions and subsequently fabricated into retail cuts. Inside round, outside round, sirloin tip and rib steaks were placed in retail packages and displayed at 2°C for 4 days. Each steak was assigned daily scores for surface discoloration and consumer acceptability by use of 7 and 8-point scales (Table 4) by a 3-member panel. Bacterial samples were obtained from wholesale cuts prior to and after storage and from retail cuts prior to and following display. Psychrotrophic counts were determined following incubation at 5°C for 7 days on

standard plate count agar. Inside round, outside round, sirloin tip and rib steaks were cooked in a 177°C oven to an internal temperature of 75°C. A 7-member trained sensory panel evaluated samples of each steak for flavor, juiciness, tenderness and overall satisfaction by use of an 8-point hedonic scale (Table 4).

Results and Discussion

Mean values for shrinkage, muscle color and appearance of subcutaneous fat in test shipments 1, 2, 3, 4 and 5 are presented in Table 1. Temperature conditions within specific loads were affected by loading patterns, product densities, positions of palletized product or paper partitions, thermostat settings and the presence or absence of air conveyance ducts and were generally inadequate for the maintenance of beef quality (Rea, Smith and Carpenter, 1972). The use of polyethylene bags or polyvinyl chloride film significantly ($P<.05$) reduced intransit shrinkage as compared to unprotected cuts or quarters in 7 of 16 comparisons (Table 1). It was difficult to establish the effectiveness of paper bags in reducing shrinkage intransit because of excessive tearing during loading, shipment and unloading, but significant ($P<.05$) reductions in weight loss were noted in 5 of 16 comparisons.

Muscle color from cuts protected by polyethylene or polyvinyl chloride was significantly ($P<.05$) brighter than that of unprotected cuts in 2 of 6 comparisons (Table 1). Beef cuts protected by polyethylene bags were more desirable in appearance of subcutaneous fat than unprotected cuts in 9 of 10 comparisons. Cuts wrapped in polyvinyl chloride film were superior ($P<.05$) in fat appearance to unprotected cuts in 7 of 10 comparisons. When polyethylene bags and polyvinyl chloride film were removed upon arrival at the destination, the surfaces of cuts were more moist than corresponding surfaces of cuts that were transported unprotected or in paper bags. Since an increase in Aw could increase bacterial growth, prolonged storage in plastic wrapping materials is not feasible. Microbial counts from cuts or quarters in these

test shipments were significantly different only in comparison 1, but trended toward significance in shipment 5. These data suggest that polyethylene bags and polyvinyl chloride film should not be allowed to remain on quarters or primal cuts longer than 7 days following application.

Mean values for shrinkage, bacterial count and odor in storage trials 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 are presented in Table 2. Rounds and chucks (trial 1) and quarters (trial 10) protected by paper bags sustained less shrinkage (1.8%, $P>.05$ and 0.8%, $P<.05$, respectively) than unprotected cuts or quarters, but bacterial counts and odor scores did not differ between treatments. Quarters stored in polyethylene bags shrank significantly less than counterpart cuts stored in paper bags and those which were unprotected during storage (trial 10). The use of polyvinyl chloride film (trial 9) or rubber hydrochloride film (trials 3, 6, and 10) was associated with significant ($P<.05$) decreases in shrinkage in comparison to losses sustained by unprotected cuts or quarters. Unfortunately, bacterial counts increased and off-odor incidence increased as the period of storage increased from 5 (trial 9) to 13 (trial 3) days. Storage in chloride film for 5 days significantly ($P<.05$) decreased shrinkage yet had no effect on bacterial counts or incidence of off-odors. Storage intervals of 8 days or longer in chloride film resulted in increased bacterial counts (3 of 3 trials) and undesirable odor scores (2 of 3 trials). Primal cuts stored in vacuum packages shrank significantly ($P<.05$) less than unprotected cuts in 5 of 5 comparisons. Vacuum packaged cuts displayed higher numerical bacterial counts than unprotected cuts in 4 of 5 trials and lower numerical odor scores in 5 of 5 trials but the differences were significant ($P<.05$) only in trials 4 (bacteria), 5 (odor) and 7 (bacteria).

Data from storage trial 11 are presented in Figure 1 and Table 3. Bacterial counts for primal cuts from the forequarter and hindquarter were generally 50 to 100 million higher for cuts wrapped with PVC film than for

those stored in vacuum packages (Figure 1). The aerobic, moist environment on the surface of cuts wrapped in PVC film undoubtedly enhanced bacterial growth since low initial counts ($\log_{10} < 2.0$) were detected on cuts in both packaging treatments. The magnitude of the bacterial counts in the present study were intermediate to those reported by Rea (1970) for cuts stored 7 or 13 days using the same packaging materials. Wholesale cuts which exhibited high bacterial counts after 11 days of storage had a high incidence of off-odor development, regardless of packaging method. Scores for propriety of vacuum, muscle color and fat appearance were not associated with bacterial counts on wholesale cuts.

Data regarding the effects of protective wrapping material on the retail caselife of steaks from cuts in storage trial 11 are presented in Table 3. Muscle color differed little until the 4th and 5th days of retail display, at which time steaks from wholesale cuts wrapped in PVC were darker than those from vacuum packaged cuts. Overall desirability ratings were lower at each interval in the retail case for steaks from ribs which had been stored in PVC film as compared to steaks from vacuum packaged ribs. Steaks from ribs wrapped in PVC film exhibited both peripheral and surface discoloration at a much faster rate than steaks from vacuum packaged ribs during the period in the retail display case. Using the criteria established by Rea (1970), steaks from vacuum packaged ribs were unacceptable on the 4th day of retail display, while those from ribs wrapped in PVC film were unacceptable after the 3rd day of retail case display. Rea (1970) observed that rib steaks from vacuum packaged ribs were unacceptable after 4 days, while those from ribs wrapped in PVC were unacceptable after 2 days. Under the conditions of this experiment, steaks from ribs stored in vacuum packages have approximately 1 day of increased caselife in comparison to steaks from ribs wrapped in PVC film.

Data regarding the effects of CO_2 and vacuum packaging systems on certain

wholesale round and retail cut traits are presented in Table 4. Vacuum packaged rounds displayed less ($P<.05$) muscle surface discoloration and trim loss, lower ($P<.05$) off-odor incidence and bacterial counts, and higher ($P<.05$) overall desirability scores than CO_2 chilled rounds at both postmortem intervals (10 and 17 days). Retail cuts from vacuum packaged rounds exhibited higher ($P<.05$) consumer acceptability ratings (inside and outside round steaks) at both postmortem intervals. Additional advantages in favor of vacuum packaging, observed only at the 17 day postmortem interval, included higher ($P<.05$) scores for appearance of the subcutaneous fat, less ($P<.05$) surface discoloration on sirloin tip steaks and greater ($P<.05$) consumer acceptability for sirloin tip steaks after 4 days of retail display. The data of the present study suggest that vacuum packaged rounds were more desirable in appearance (muscle and fat), had lower bacterial counts, less off-odor, required much less trimming prior to cutting and produced retail cuts with greater expected caselife than rounds packaged with carbon dioxide pellets.

Comparable data concerning the effects of CO_2 and vacuum packaging systems on certain wholesale rib and retail cut traits are presented in Table 5. Analyses of these data are complicated by the failure of vacuum packaged ribs to maintain satisfactory conditions of air exclusion (vacuum scores of 2.0 and 1.7 for 10 and 17 day intervals, respectively). Under the conditions specified, CO_2 chilling resulted in ribs which had ($P<.05$) a lower incidence of off-odors, less surface discoloration and which were ($P<.05$) more desirable in overall acceptability (wholesale and retail cuts) than vacuum packaged ribs after a postmortem interval of 10 days. Although CO_2 chilling of beef ribs appears advantageous at 10 days, its use for 17 days of storage is not feasible. Ribs chilled with CO_2 were less desirable in overall appearance, had higher bacterial counts and yielded retail cuts which sustained greater surface discoloration, were less acceptable to consumers and which were less tender and less satisfactory in overall palatability than vacuum packaged ribs.

Summary

Test shipments and storage trials involving 1225 beef quarters or wholesale cuts were conducted to investigate the effects of protective packaging systems on certain wholesale and retail cut characteristics. Polyethylene bags and polyvinyl chloride film reduced intransit shrinkage and improved muscle color and subcutaneous fat appearance in comparison to unprotected cuts during test shipments. The use of chloride films for storage of beef cuts for 5 days decreased shrinkage yet had no effect on bacterial counts or incidence of off-odors. Storage intervals of 8 days or longer in chloride film resulted in increased bacterial counts and undesirable odor scores and thus would not be feasible. The success of vacuum packaging as a means of preservation for beef cuts depends greatly upon the degree of vacuumization achieved. Steaks from vacuum packaged ribs had 1 day of additional caselife in comparison to ribs wrapped in polyvinyl chloride film (storage interval of 11 days) and were more acceptable to consumers in appearance and palatability than ribs chilled with carbon dioxide (storage interval of 17 days). Vacuum packaged rounds were more desirable in muscle and fat appearance, had lower bacterial counts, less off-odor, required much less trimming prior to cutting and produced retail cuts with greater expected caselife than rounds which were chilled with carbon dioxide pellets.

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TABLE 1. MEAN VALUES FOR SHRINKAGE, MUSCLE COLOR AND APPEARANCE OF SUBCUTANEOUS FAT IN TEST SHIPMENTS 1, 2, 3, 4 AND 5.

Test shipment	Item[a]	N	Distance traveled (miles)	Time intransit (hr)	Trait[b]	Treatment			
						Unprotected	Paper bag	Polyethylene bag	Polyvinyl chloride film
1	Rb	63	560	26	Shrinkage	0.6[c]		0.6[c]	
2	Ch	25	270	19	Shrinkage	0.7[c]	0.3[c]	0.2[c]	0.4[c]
					Muscle color	4.0[c]	4.2[c]	4.7[c]	4.7[c]
					Fat appearance	2.6[c]	2.7[c]	3.7[d]	3.0[cd]
2	Rd	50	270	19	Shrinkage	0.7[c]	0.4[c]	0.7[c]	0.3[c]
					Muscle color	1.9[c]	2.9[c]	2.8[c]	3.4[c]
					Fat appearance	3.5[c]	3.8[c]	4.0[c]	3.5[c]
2	FQ	22	270	19	Shrinkage	0.5[c]	0.4[c]		0.4[c]
2	HQ	22	270	19	Shrinkage	1.0[c]	0.6[cd]		0.3[d]
3	Ln	15	1200	120	Shrinkage	2.4[c]	1.6[c]	1.8[c]	0.9[c]
					Muscle color	1.7[c]	3.0[cd]	5.3[e]	3.5[d]
					Fat appearance	3.0[c]	3.7[cd]	4.0[d]	4.0[d]
3	Rd	50	1200	120	Shrinkage	2.9[c]	2.2[d]	1.5[e]	1.4[e]
					Fat appearance	2.1[c]	3.4[d]	4.9[d]	5.2[d]
3	FQ	32	1200	120	Shrinkage	1.2[c]	0.8[d]	0.5[de]	0.3[e]
3	HQ	52	1200	120	Shrinkage	1.3[c]	1.1[cd]	0.7[d]	0.8[d]
4	Sd	85	1000	35	Shrinkage	0.5[cd]	0.6[c]	0.2[e]	0.3[de]
					Fat appearance	4.8[c]	5.1[c]	5.8[d]	5.5[d]
4	Ch	30	1000	35	Shrinkage	0.3[c]	0.4[c]	0.1[c]	0.1[c]
					Fat appearance	3.6[c]	3.6[c]	4.4[d]	4.7[d]
4	Rd	50	1000	35	Shrinkage	0.3[c]	0.1[c]	0.1[c]	0.1[c]
					Fat appearance	4.4[c]	4.7[c]	5.3[d]	5.6[d]
4	Rb	15	1000	35	Shrinkage	1.3[c]	0.0[c]	0.6[c]	0.1[c]
					Fat appearance	4.7[c]	4.5[c]	6.0[d]	6.0[d]
5	Sd	90	1350	85	Shrinkage	1.9[c]	0.2[d]	0.1[d]	0.1[d]
					Fat appearance	1.7[c]	2.1[cd]	2.5[d]	2.2[cd]
5	Ch	70	1350	85	Shrinkage	1.9[c]	0.9[d]	0.3[de]	0.1[e]
					Muscle color	1.3[c]	1.7[c]	2.4[d]	2.5[d]
					Fat appearance	4.1[c]	4.4[d]	4.5[d]	4.6[d]
5	Rd	15	1350	85	Shrinkage	2.7[c]	1.5[d]	0.8[de]	0.4[e]

[a] Abbreviations are as follows: Rd = round, Ch = chuck, Ln = loin, Sd = side, Rb = rib, FQ = forequarter and HQ = hindquarter.

[b] Shrinkage loss computed as percent weight lost; muscle color scores based on a 9-point scale (9 = very light cherry red; 1 = black); fat appearance scores based on a 6-point scale (6 = very fresh appearance; 1 = severe or extensive discoloration or desiccation).

[cde] Mean values on the same horizontal line bearing different superscripts differ signficantly (P<.05).

TABLE 2. MEAN VALUES FOR SHRINKAGE, BACTERIAL COUNT AND ODOR IN STORAGE TRIALS 1, 2, 3, 4, 5, 6, 7, 8, 9 AND 10.

Storage trial	Item[a]	N	Storage interval[b] (days)	Trait[c]	Treatment				
					Unprotected	Paper bag	Polyethylene bag	Chloride film[d]	Vacuum package
1	Rd,Ch	16	13 (2-15)	Shrinkage	2.3[e]	0.5[e]			
				Bacterial count	5.5[e]	5.5[e]			
				Odor score	4.0[e]	3.9[e]			
2	Rb,Sh,Si	24	13 (2-15)	Shrinkage	3.9[e]				1.1[f]
				Bacterial count	6.5[e]				7.1[e]
				Odor score	3.7[e]				3.6[e]
3	Rd,Ch	20	13 (2-15)	Shrinkage	3.0[e]			0.4[f]	
				Bacterial count	4.8[e]			7.8[f]	
				Odor score	4.0[e]			1.7[f]	
4	Rb,Sh,Si	30	13 (2-15)	Shrinkage	3.0[e]				0.8[f]
				Bacterial count	4.0[e]				5.8[f]
				Odor score	4.0[e]				3.5[e]
5	Ch,Rb,Sh,Si,Rd	54	10 (5-15)	Shrinkage	2.8[e]				0.5[f]
				Bacterial count	4.6[e]				4.6[e]
				Odor score	4.0[e]				2.8[f]
6	Rd,Ch	20	10 (5-15)	Shrinkage	2.3[e]			0.2[f]	
				Bacterial count	5.2[e]			8.0[f]	
				Odor score	4.0[e]			1.5[f]	
7	Rb,Sh,Si	30	10 (5-15)	Shrinkage	3.8[e]				0.5[f]
				Bacterial count	4.8[e]				6.6[f]
				Odor score	4.0[e]				3.4[e]
8	Ch,Rb,Sh,Si,Rd	69	7 (8-15)	Shrinkage	1.1[e]				0.5[f]
				Bacterial count	4.0[e]				4.4[e]
				Odor score	4.0[e]				3.0[e]
9	FQ,HQ	14	5 (2-7)	Shrinkage	1.3[e]			0.2[f]	
				Bacterial count	3.4[e]			3.4[e]	
				Odor score	4.0[e]			4.0[e]	
10	FQ,HQ	20	8 (7-15)	Shrinkage	1.3[e]	0.5[f]	0.1[g]	0.2[fg]	
				Bacterial count	3.9[e]	3.7[e]	3.5[e]	5.5[f]	
				Odor score	4.0[e]	4.0[e]	4.0[e]	3.0[e]	

[a] Abbreviations are as follows: Rd = round, Ch = chuck, Sh = shortloin, Si = sirloin, Rb = rib, FQ = forequarter and HQ = hindquarter.

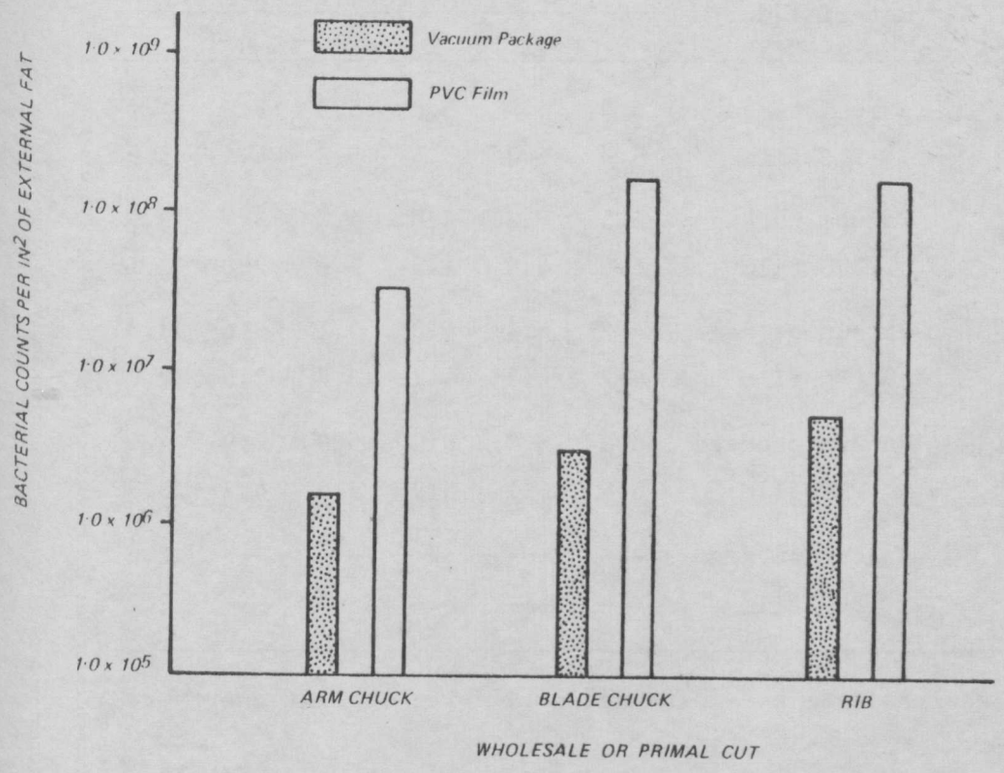
[b] Storage intervals are as follows: 13 (2-15) = days in storage (day postmortem trial was initiated - day postmortem trial was concluded.)

[c] Shrinkage loss computed as percent of weight lost; bacterial counts expressed on a $\log_{10}$ basis; odor scores were based on a 4-point scale (4 = no off-odor; 1 = extreme off-odor).

[d] Two types of chloride film were employed (PVC = polyvinyl chloride; RHC = rubber hydrochloride). PVC was used in trial 9, RHC was used in trials 3, 6 and 10.

[efg] Mean values on the same horizontal line bearing different superscripts differ significantly ($P<.05$).

FIGURE 1. BACTERIAL COUNTS FOR BEEF WHOLESALE OR PRIMAL CUTS STORED FOR 11 DAYS IN EITHER VACUUM PACKAGE OR PVC FILM



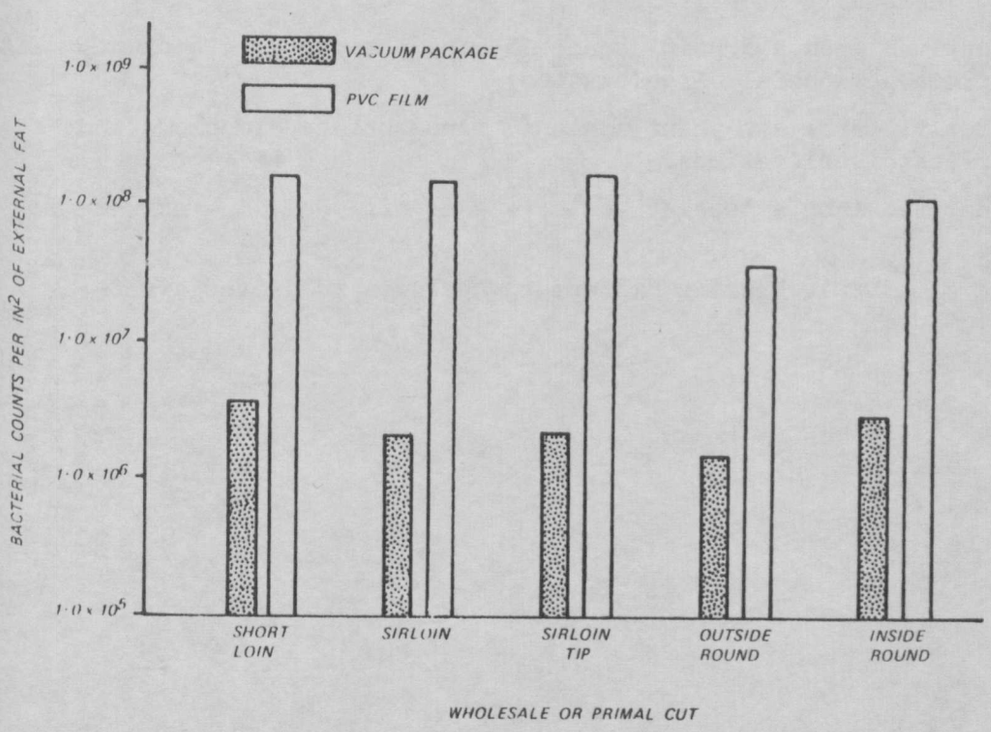


TABLE 3. EFFECTS OF PROTECTIVE WRAPPING MATERIAL ON THE RETAIL CASELIFE OF RIB STEAKS FROM CUTS IN STORAGE TRIAL 11.

Trait	Wrapping material during storage	Time in the retail case, days					
		0	1	2	3	4	5
Muscle color[a]	Vacuum package	5.9	5.9	5.6	5.3	5.0	4.7[f]
	PVC film	5.6	5.8	5.4	5.3	4.4	3.9[g]
Overall desirability[b]	Vacuum package	5.5	5.2	4.8	4.2	3.7	3.0[f]
	PVC film	5.0	4.9	4.3	3.6	2.8	2.1[g]
Peripheral discoloration[c]	Vacuum package	4.2	4.4	4.3	4.1	3.6	3.5[f]
	PVC film	4.2	4.3	4.1	3.7	2.9	2.7[g]
Surface discoloration[d]	Vacuum package	6.3	6.3	6.2	5.9	4.9	4.6[f]
	PVC film	6.3	6.1	5.9	5.2	4.1	3.7[g]
Odor[e]	Vacuum package	---	---	---	---	---	2.6[f]
	PVC film	---	---	---	---	---	2.1[g]

[a]Mean values derived from a 9-point scale (9 = very bright cherry red; 1 = black).

[b]Mean values derived from a 8-point hedonic scale (8 = extremely desirable; 1 = extremely undesirable).

[c]Mean values derived from a 5-point scale (5 = no peripheral discoloration; 1 = extreme peripheral discoloration).

[d]Mean values derived from a 7-point scale (7 = no surface discoloration; 1 = total surface discoloration).

[e]Mean values derived from a 4-point scale (4 = no off-odor; 1 = extreme off-odor).

[fg]Means for the same trait bearing different superscripts differ significantly ($P<.05$).

TABLE 4. EFFECTS OF TWO PACKAGING SYSTEMS FOR DISTRIBUTION OF BOXED BEEF ON CERTAIN WHOLESALE ROUND AND RETAIL CUT TRAITS

Trait	Postmortem interval			
	10 days		17 days	
	Carbon dioxide chilling	Vacuum packaging	Carbon dioxide chilling	Vacuum packaging
Wholesale cuts				
Vacuum score[a]	----	3.1	----	3.2
Fat appearance[b]	3.9[f]	4.0[f]	2.2[g]	3.8[f]
Surface discoloration[c]	2.5[g]	4.8[f]	2.0[g]	5.1[f]
Overall desirability[d]	3.8[g]	6.4[f]	3.2[g]	6.0[f]
Odor[e]	2.3[g]	3.1[f]	1.4[g]	3.2[f]
Bacterial count (log_{10})	7.3[g]	4.6[f]	7.4[g]	5.8[f]
Unsaleable trim (kg)	0.4[g]	0.1[f]	1.1[g]	0.1[f]
Retail cuts				
Surface discoloration[c]-inside round	3.9[f]	3.8[f]	4.2[f]	4.4[f]
Surface discoloration[c]-outside round	3.9[f]	3.9[f]	4.1[f]	4.2[f]
Surface discoloration[c]-sirloin tip	3.4[f]	3.3[f]	2.8[g]	3.7[f]
Consumer acceptability[d]-inside round	3.7[g]	4.5[f]	4.2[g]	4.7[f]
Consumer acceptability[d]-outside round	3.7[g]	4.6[f]	4.2[g]	4.5[f]
Consumer acceptability[d]-sirloin tip	3.5[f]	3.6[f]	3.1[g]	4.3[f]
Overall satisfaction[d]-inside round	5.4[f]	5.4[f]	5.6[f]	5.4[f]
Overall satisfaction[d]-outside round	4.9[f]	5.0[f]	5.1[f]	5.0[f]
Overall satisfaction[d]-sirloin tip	5.2[f]	5.5[f]	5.6[f]	6.0[f]
Bacterial count (log_{10})	7.1[g]	5.9[f]	5.9[f]	6.4[f]

[a]Mean values derived from a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[b]Mean values derived from a 6-point scale (6 = very fresh; 1 = severe discoloration).

[c]Mean values derived from a 7-point scale (7 = no surface discoloration; 1 = total surface discoloration).

[d]Mean values derived from a 8-point hedonic scale (8 = extremely desirable; 1 = extremely undesirable).

[e]Mean values derived from a 4-point scale (4 = no off-odor; 1 = extreme off-odor).

[fg]Means in the same postmortem interval and on the same horizontal line bearing different superscripts differ significantly ($P<.05$).

TABLE 5. EFFECTS OF TWO PACKAGING SYSTEMS FOR DISTRIBUTION OF BOXED BEEF ON CERTAIN WHOLESALE RIB AND RETAIL CUT TRAITS

Trait	Postmortem interval: 10 days — Carbon dioxide chilling	10 days — Vacuum packaging	17 days — Carbon dioxide chilling	17 days — Vacuum packaging
Wholesale cuts				
Vacuum score[a]	---	2.0	---	1.7
Fat appearance[b]	4.1[g]	3.7[g]	4.2[g]	3.1[h]
Muscle color[c]	6.5[g]	5.7[g]	6.3[g]	6.1[g]
Surface discoloration[d]	4.6[g]	3.3[h]	2.8[g]	2.3[g]
Overall desirability[e]	5.7[g]	4.8[h]	4.2[h]	4.6[g]
Odor[f]	3.6[g]	3.1[h]	2.1[g]	2.1[g]
Bacterial count ($\log_{10}$)	5.4[g]	4.9[g]	7.2[h]	5.9[g]
Unsaleable trim (kg)	none	none	0.3[g]	0.2[g]
Retail cuts				
Surface discoloration[d]	6.2[g]	6.2[g]	5.9[h]	6.3[g]
Consumer acceptability[e]	7.4[g]	6.5[h]	5.7[h]	6.6[g]
Odor[f]	2.2[g]	2.2[g]	2.1[g]	2.4[g]
Bacterial count ($\log_{10}$)	5.5[g]	5.3[g]	5.6[g]	4.7[g]
Flavor[e]	6.5[g]	6.5[g]	6.4[g]	6.6[g]
Tenderness[e]	5.9[g]	6.1[g]	6.1[h]	6.7[g]
Overall satisfaction[e]	5.8[g]	5.7[g]	6.1[h]	6.7[g]

[a]Mean values derived from a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[b]Mean values derived from a 6-point scale (6 = very fresh; 1 = severe discoloration).

[c]Mean values derived from a 9-point scale (9 = very bright cherry red; 1 = black).

[d]Mean values derived from a 7-point scale (7 = no surface discoloration; 1 = total surface discoloration).

[e]Mean values derived from a 8-point hedonic scale (8 = extremely desirable; 1 = extremely undesirable).

[f]Mean values derived from a 4-point scale (4 = no off-odor; 1 = extreme off-odor).

[gh]Means in the same postmortem interval and on the same horizontal line bearing different superscripts differ significantly ($P<.05$).