COMPARATIVE COST ANALYSIS OF CARBON DIOXIDE AND VACUUM PACKAGED BOXED BEEF: A CASE STUDY

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Summary and Conclusions

Although the majority of beef is still distributed from packer to retailer as hanging beef, boxed beef has become an increasingly important method of distribution. This research was intended to provide cost and savings information, for a case study, concerning the use of carbon dioxide and vacuum packaging methods of boxed beef distribution. The two systems were evaluated with respect to shrink, trim loss, and retail case life so as to provide a cost-benefit comparison of the two boxed beef methods.

For this research, the carbon dioxide method consisted of placing subprimal ribs or rounds in a polyethylene lined cardboard box with bagged carbon dioxide pellets (about two pounds) added to the box prior to closure. The vacuum packaging technique involved drawing a partial vacuum on a laminated barrier bag containing a subprimal rib or round which was then boxed. Both methods can utilize palletization.

Information was monitored during a test shipment containing 120 boxes of beef (60 carbon dioxide and 60 vacuum packaged). An equal number of boxes of ribs and rounds were stored for 10 days and 17 days, including two days in transit. Meat specialists fabricated the subprimals into retail cuts in a manner considered typical for the retail industry. These retail cut steaks were evaluated daily for four days to determine their consumer acceptability and compare the steaks from the two boxed methods after both 10 and 17 days of storage.

Cost comparisons were made to determine the additional cost for each method as contrasted with the conventional hanging method of distribution. Thus, carcass breaking costs and general plant overhead were not included in the cost calculations for either boxed method. All data were expressed in dollars per hundredweight with separate data on ribs and rounds presented. Cost conversions were based on an assumed average dressed carcass weight of 675 pounds.

Packaging material costs were $1.217 per cwt. for ribs and $1.113 for rounds for the carbon dioxide method. The vacuum packaging material costs were $2.525 per cwt. for ribs and $1.530 for rounds. Labor costs for the carbon dioxide method were $0.770 per cwt. for ribs and $1.529 per cwt. for rounds. Vacuum packaging labor costs were $1.458 per cwt. for ribs and $1.773 per cwt. for rounds. Annual fixed costs were calculated for each additional capital equipment item required by the method. Average fixed costs were $0.014 per cwt. for ribs and $0.013 per cwt. for rounds for the carbon dioxide method and $0.134 per cwt. for ribs compared to $0.061 per cwt. for rounds for the vacuum packaged method.

The carbon dioxide method had an average total cost of $2.001 per cwt. for ribs and $4.117 per cwt. for vacuum packaging. For rounds, the average total cost was $2.655 per cwt. for carbon dioxide and $3.364 per cwt. for vacuum packaging.

Comparative net benefits associated with the two methods were determined by adjusting the value of the subprimal for both shrink and trim loss as well as the cost of packing. After 10 or 17 days of storage there was no measurable subprimal shrink for either method for either ribs or rounds. A range in trim loss was determined and net benefit data presented.

All vacuum packaged ribs in the test shipment were leakers. Under these conditions the net benefits to the carbon dioxide method exceeded vacuum packaging after either 10 or 17 day storage. Because of the rib leaker problem, a replicated experiment was conducted under laboratory conditions to evaluate ribs stored 17 days. The 10 day storage was not replicated since there was no trim loss for either method for the test shipment. After 10 days of storage the carbon dioxide method offered net benefits for ribs which were $2.116 per cwt. greater than the vacuum packaged method. This represents only packaging cost differences since there was no trim loss for either method. After 17 days vacuum packaging net benefits exceeded carbon dioxide slightly but by less than one-half of one percent.

Daily consumer acceptability scores were essentially the same for steaks fabricated from 10 day ribs for either packaging method. On the average, steaks from ribs stored 17 days received acceptable consumer acceptance scores. The one exception was steaks from the carbon dioxide method after four days of retail case life. The incidence of steaks removed for the carbon dioxide method was one of five for the third and three of five for the fourth day of retail case life while vacuum packaging had none.

Net benefits accruing to vacuum packaging of subprimal rounds averaged slightly higher compared to carbon dioxide after 10 days of storage. This was less than one-half of one percent difference, however. Net benefits favoring vacuum packaging were greater than carbon dioxide after 17 days of storage by about 2.8 percent. Thus, reduced trim loss attributed to vacuum packaging significantly more than offset the cost of packaging rounds after 17 days of storage.

Retail case life comparisons for inside and outside round steaks from the two methods of packaging yielded nearly identical results. All steaks received average scores which were in the acceptable range except for steaks from the carbon dioxide method stored 10 days (which may have resulted from a brief unexpected retail case temperature increase). However, steaks from the subprimals packaged by the carbon dioxide method had a higher incidence of steaks removed: 20 percent higher for the second day, 40 percent higher for the third day, 70 percent higher for the fourth day for steaks from subprimals stored 10 days, and 10 percent higher for fourth day of retail display for those stored 17 days.

Implications

For subprimal ribs, the carbon dioxide method of boxed shipment has a net benefit compared to vacuum packaging for 10 days storage. For 17 days, the vacuum packaging method offers a slight net benefit. This implies that for subprimal storage of up to 17 days from kill date, the carbon dioxide method net benefit is equal to or greater than the vacuum packaging method. However, if more than two days of retail case life is necessary after a subprimal storage period of 17 days, the vacuum packaging method offers a smaller incidence of pull backs than does the carbon dioxide method. This means that from a retailer's viewpoint, after 17 day subprimal storage, the retail case life benefits associated with vacuum packaging may be significant.

For rounds, the vacuum packaging method offers net benefits slightly greater than the carbon dioxide method after 10 days subprimal storage. As the subprimal storage period was extended to 17 days, the vacuum packaged method had greater net benefits than the carbon dioxide method. In addition, steaks fabricated from the vacuum packaged rounds had a smaller incidence of pull backs after the second day of retail case storage. This again can be an important factor for consideration by a retailer.

The implications are tempered by the wholesale price of beef used in the analysis above. If prices substantially advance beyond those existing at the time of this analysis, vacuum packaging net benefits would likewise increase. The converse is also true.

Further research is needed detailing the costs and product characteristics of various methods of boxed beef. For example, the amount of bone in a subprimal may result in different net benefits to packaging alternatives. Essentially no information is available concerning retail case life evaluations for various subprimal cuts shipped under an array of conditions. As the importance of semi-boneless and boneless beef distribution increases, research will be needed to evaluate cost and benefits of various wholesale and retail packaging methods.

COMPARATIVE COST ANALYSIS OF CARBON DIOXIDE AND VACUUM PACKAGED BOXED BEEF: A CASE STUDY

Thomas L. Sporleder and William J. Vastine*

Introduction

Fresh beef is distributed from packers to retail distribution centers and on to retail stores in various ways. In the retail grocery segment of the beef distribution channel, the major portion still moves fresh in the form of hanging quarters or primals. However, a recently important method of shipment to the retail grocery segment is beef in boxed, palletized form. Although no accurate data are available to document the proportion of beef which is distributed boxed versus hanging, industry consensus is that the boxed, palletized method will continue to increase in importance.

This research report provides the results of the economic phase of a larger research project conducted by the Animal Science Department, Texas A&M University, which concerns alternative methods of distribution for fresh beef. Specifically, the research reported herein relates to a comparative cost analysis of carbon dioxide and vacuum packaged boxed beef distribution. The intent is not to identify one method as superior to the other, but rather to provide objective information

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concerning relative costs and savings resulting from the two methods.

Several research studies have been completed which analyze various aspects of the physical distribution system for fresh beef. Some take a systems approach [1, 2] while others are oriented to a particular segment of the distribution channel [4, 5, 6, 7]. However, information specifically related to economic comparisons of alternative methods of boxed beef distribution is scarce, primarily due to the relatively recent utilization of the boxed method of handling.

The carbon dioxide method of boxed beef consists of placing a sheet of polyethylene in a cardboard box, placing either a primal or subprimal cut on the polyethylene which is then folded over the meat. Just prior to box closure, a small perforated polyethylene bag of carbon dioxide pellets (typically about two pounds) is placed in the box which may then be palletized. Other carbon dioxide methods consist of utilizing carbon dioxide snow or loose carbon dioxide pellets. However, for this research bagged carbon dioxide pellets were used.

The vacuum packaged method is well known and consists of drawing a partial vacuum on a laminated barrier bag containing either a primal or subprimal cut. These vacuum packaged cuts then may be placed in boxes or other master containers for palletized storage and/or shipment.

Objectives

The specific objectives of the economic phase of this research were: 1) to identify additional costs associated with utilization of carbon dioxide and vacuum packaged boxed beef at the packer level, and 2) to evaluate the two systems with respect to shrink, trim loss, and retail case life so as to provide a cost-benefit comparison of the two boxed beef methods.

Methodology

A case study approach was utilized for this research because primary data were collected in conjunction with a test shipment. The logistic difficulties involved in attempting to collect data in conjunction with test shipments over a number of packers, given limited resources, deemed the case study approach necessary.

Cooperators for the test shipment were established and economic data were collected during the first quarter of 1973. The test shipment contained both carbon dioxide and vacuum packaged rounds (I.M.P.S. 163 or 164) and ribs (I.M.P.S. 103 or 104).[1/] Shipment via refrigerated truck trailer was monitored with respect to shrink, bacterial changes, and in-transit temperatures. Total in-transit time was 2 days, one day from packer to distribution center and another from distribution center to the Animal Science Laboratories at Texas A&M University.

Both the carbon dioxide and vacuum packaged boxes of rounds and ribs were processed and loaded in the manner customary for normal shipments. A total of 120 boxes were included in the test shipment. These 120 boxes were composed of 60 carbon dioxide and 60 vacuum packaged boxes. Of the 60 boxes packed with carbon dioxide, 30

[1/] Institutional Meat Purchase Specifications [4].

contained subprimal ribs and 30 contained subprimal rounds. Similarly, 30 of the 60 boxes containing vacuum packaged subprimals were ribs and 30 were rounds (Figure 1).

To investigate shrink and retail case life, the various subprimals were held in storage prior to fabrication into retail cuts for either 10 or 17 days from kill date (Figure 2). These 10 or 17 day "storage" periods included the previously mentioned 2 days in transit. Of the 30 boxes of carbon dioxide packed ribs, 15 were held 10 days while the remaining 15 were held 17 days. Similarly 15 boxes of the 30 vacuum packaged ribs were held 10 days while 15 were held 17 days. Exactly these same storage treatments prior to retail cut fabrication were applied to the 60 rounds (Figure 1).

After completion of either the 10 or 17 day storage period, retail cuts were fabricated from each subprimal. These individual cuts were retail packaged in the typical tray with over-wrap and placed in a retail case. Each retail cut was evaluated daily for 4 days with respect to product characteristics (Figure 2). Details of the product characteristics such as bacterial count, temperatures, odor and color scores, trim loss, and shrink for both the subprimals and retail cuts are reported in Motycka [3]. Appendix A of this report contains a selected summary of these data.

Comparative Costs

The purpose of the cost analysis was to provide information on the additional costs incurred at the processor level for boxed beef

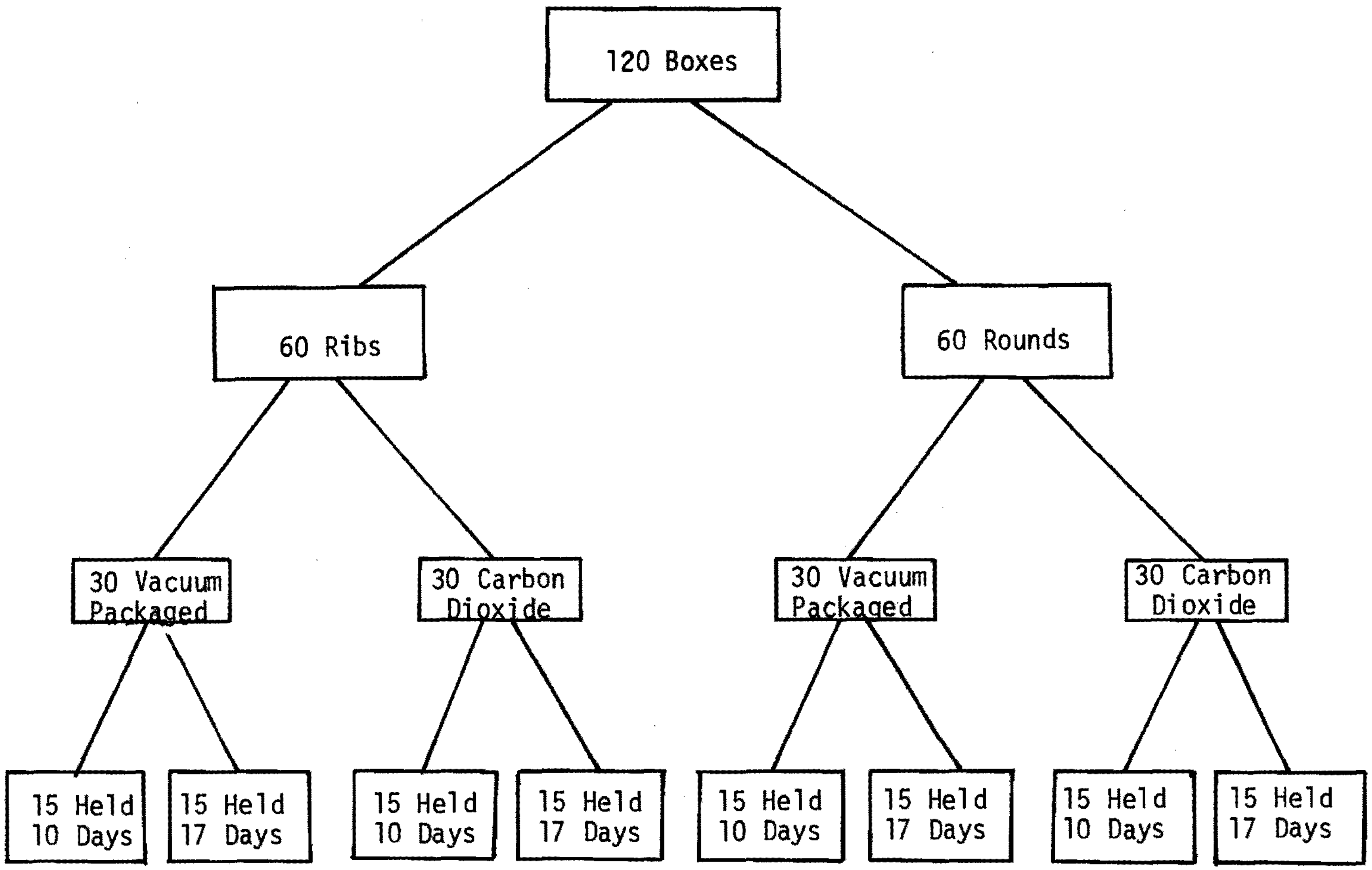

Figure 1. Design of test by type of package, subprimal, and subprimal storage length

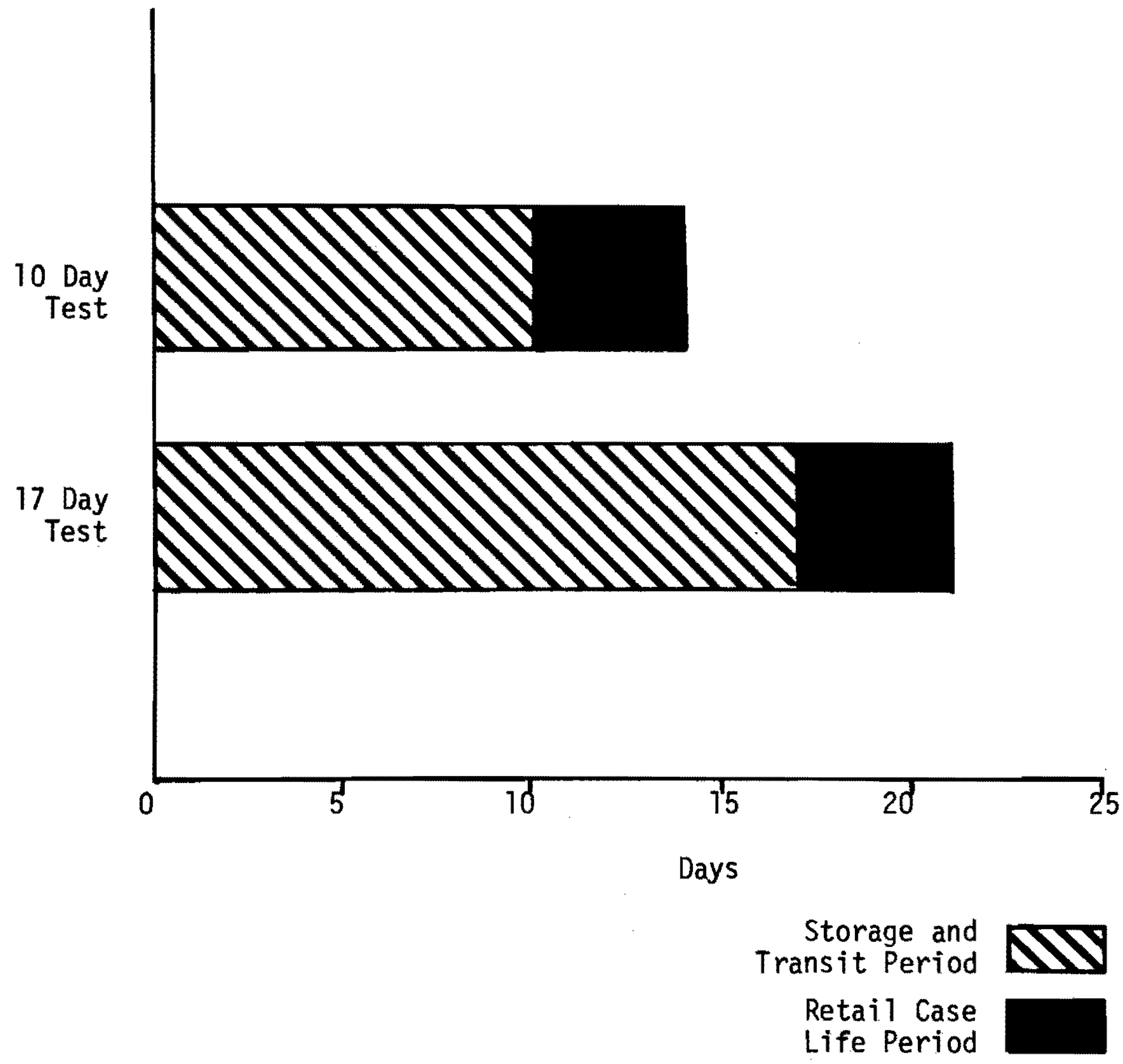

Figure 2. Design of test shipment by length of storage and transit period and retail case life period from date of slaughter for both carbon dioxide and vacuum packaged subprimals

distribution as opposed to the more conventional hanging method of distribution. Accordingly, only the additional costs associated with packaging and boxing were obtained.[1/] Carcass breaking costs, cooler storage costs, and general plant overhead were not included in the costs calculated for either boxed method. However, items such as additional labor expense for breaking rounds necessary for boxed shipment rather than hanging was included. These items are discussed in detail below.

The detailed information on cost was collected prior to the test shipment from the cooperating packing plant. Separate cost data on rib and round subprimals were maintained throughout the analysis. All data are presented on a dollars per hundredweight basis and aggregated sufficiently to maintain their confidentiality. Throughout this report, cost conversions to dollars per hundredweight were made under the assumption that fed slaughter cattle yield, on the average, a dressed carcass of 675 pounds.

The additional costs associated with the carbon dioxide and vacuum packaged methods were obtained for three general categories: 1) variable cost of material, 2) variable cost of labor, and 3) fixed cost of capital equipment. These costs are discussed in the following sections.

Material Cost

Additional material cost associated with the carbon dioxide operation include the boxes, box make-up, polyethylene liner, the carbon dioxide pellets, and the bag in which they are contained. Including a waste

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[1/] Truck transportation rates were assumed equal for boxed and hanging beef.

factor of 3 percent on total material cost, the carbon dioxide method material cost \$1.217 per hundredweight (cwt.) for ribs compared to \$1.113 for rounds, Table 1. The box and box make-up, exclusive of labor, represented 77.0 percent of total material cost while the cost of the carbon dioxide pellets represented another 13.9 percent of total material cost. Thus, the box and carbon dioxide pellets accounted for nearly 91 percent of the additional material cost necessary for the carbon dioxide method.

The material cost associated with the vacuum packaged method included the box, box make-up, laminated barrier bags, clips, and bone-guard (for ribs only). Again including a waste factor of 3 percent on total material cost, the vacuum packaged method material cost \$2.525 per cwt. for ribs compared to \$1.530 for rounds, Table 1. The box and box make-up constituted only 37.1 percent of total material cost for ribs, while the barrier bags, clips, and bone-guard accounted for another 61.9 percent. For rounds, the box and box make-up constituted 56.0 percent of total material cost with the bag and clip representing another 41.1 percent of total material cost.

Labor Cost

Labor cost associated with both the carbon dioxide and vacuum packaged methods was determined from the point immediately after fabrication of a carcass into primals or subprimals. Included in the labor cost for rounds was additional table labor for trimming the

Table 1. Cost of material, carbon dioxide and vacuum packaged boxed rib and round primals.

Item	Ribs		Rounds	
	CO_2	Vacuum	CO_2	Vacuum
		($/cwt.)		
Boxes[1/]	0.938	0.938	0.857	0.857
Liner[2/]	0.075	-	0.069	-
Bags, Clips, Bone-guard	-	1.514	-	0.628
CO_2	0.169	-	0.154	-
Miscellaneous[3/]	0.035	0.073	0.032	0.045
Total	1.217	2.525	1.112	1.530

[1/] All cost incurred for box make-up are also included. Storage, capital equipment for make-up, glue, and the cost of the sealing operation are included, but not labor.

[2/] This is the polyethylene liner used inside the box for the carbon dioxide method only.

[3/] Includes a 3 percent waste factor on total material cost.

Source: Primary Data

center cut shank and removing the Aitch bone. This table work was included since it represented additional labor for a boxed round compared to a hanging round.

For either method, labor cost was calculated at prevailing union scale plus employer contributions of fringe benefits, and averaged $6.31 per hour. Labor costs will not be presented in detail so that confidentiality is protected. Also, the labor costs calculated reflect a fatigue allowance of approximately 25 percent.

For the carbon dioxide method, labor cost for the following functions were included:

1) box make-up
2) placing polyethylene liner, meat, and carbon dioxide pellets in a box
3) box closure
4) weighing, storing, palletizing, and loading
5) miscellaneous labor and additional table work required for boxing rounds.

No administrative, janitorial, or other overhead labor was included.

The total labor cost for carbon dioxide ribs was $0.770 per cwt. compared with $1.529 per cwt. for rounds. This marked difference between ribs and rounds in labor cost is attributable to the additional table work required for the boxing operation. For the round, additional table work labor for boxing accounted for 57.4 percent of the total labor cost. Of course, this additional table work is not required for ribs.

For the vacuum packaged method, labor cost for the following functions were included:

1) box make-up

2) placing meat in barrier bag

3) drawing vacuum

4) placing vacuum packaged subprimal in box

5) box closure

6) weighing, storing, palletizing, and loading

7) miscellaneous labor and additional table work required for boxing rounds.

Again, no administrative, janitorial, or other overhead labor was included.

The total labor cost for the vacuum packaged method for ribs was \$1.458 per cwt. compared with \$1.773 per cwt. for rounds.

Total Variable Cost

The labor and material costs are additive. Summed, they represent total variable cost. The material cost component accounted for 61.2 percent of total variable cost for carbon dioxide ribs compared to 63.4 percent for vacuum packaged ribs, Figure 3. For rounds, the proportion of total variable cost attributable to material cost was 42.1 percent for the carbon dioxide method contrasted to 46.3 percent for the vacuum packaged method, Figure 4. Thus, the methods of packaging had a similar relative relationship between labor and material cost.

Fixed Cost

In both the carbon dioxide and vacuum packaged methods, certain additional capital equipment is necessary. Once a decision is made to

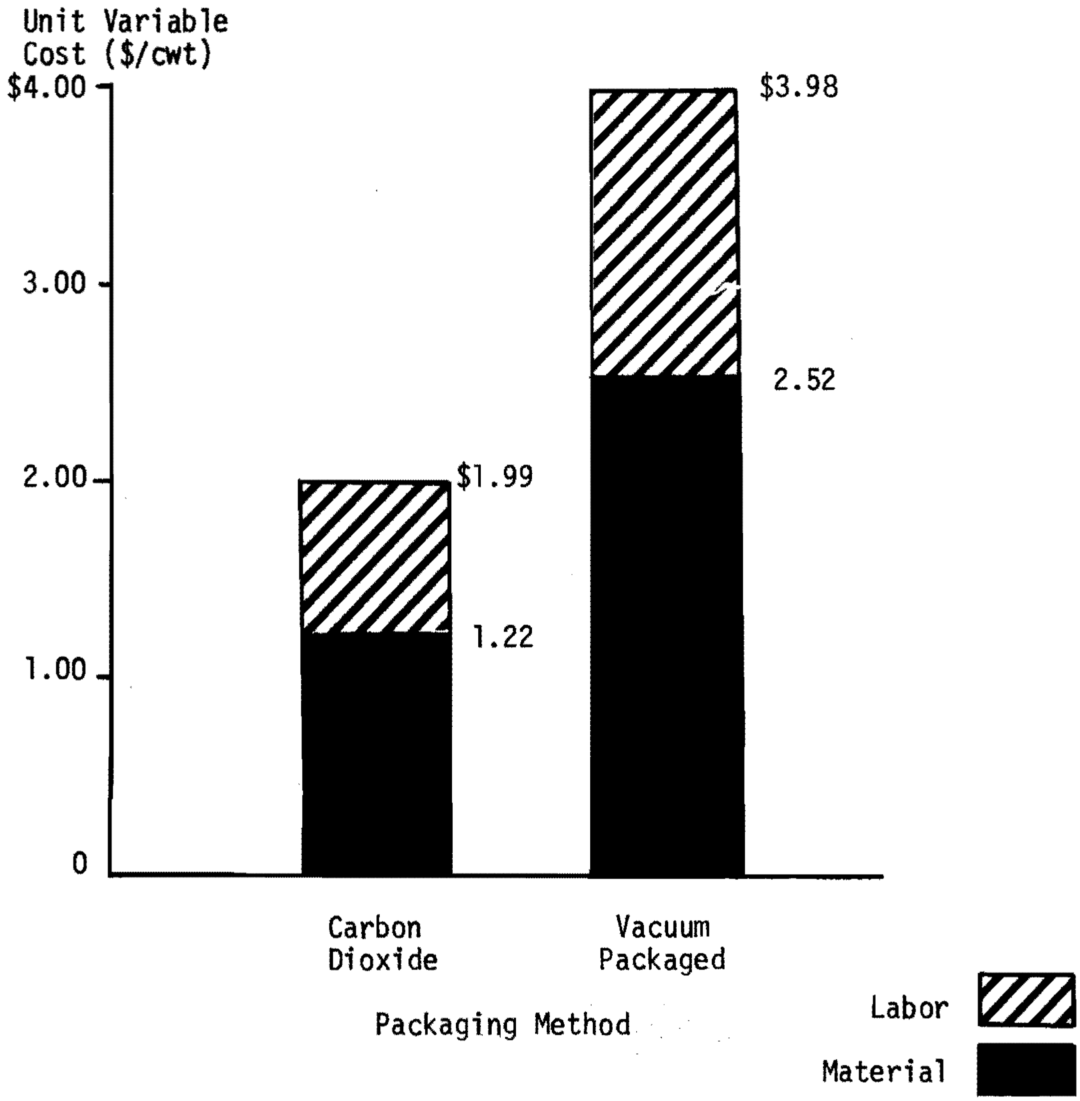

Figure 3. Unit variable cost, rib subprimals

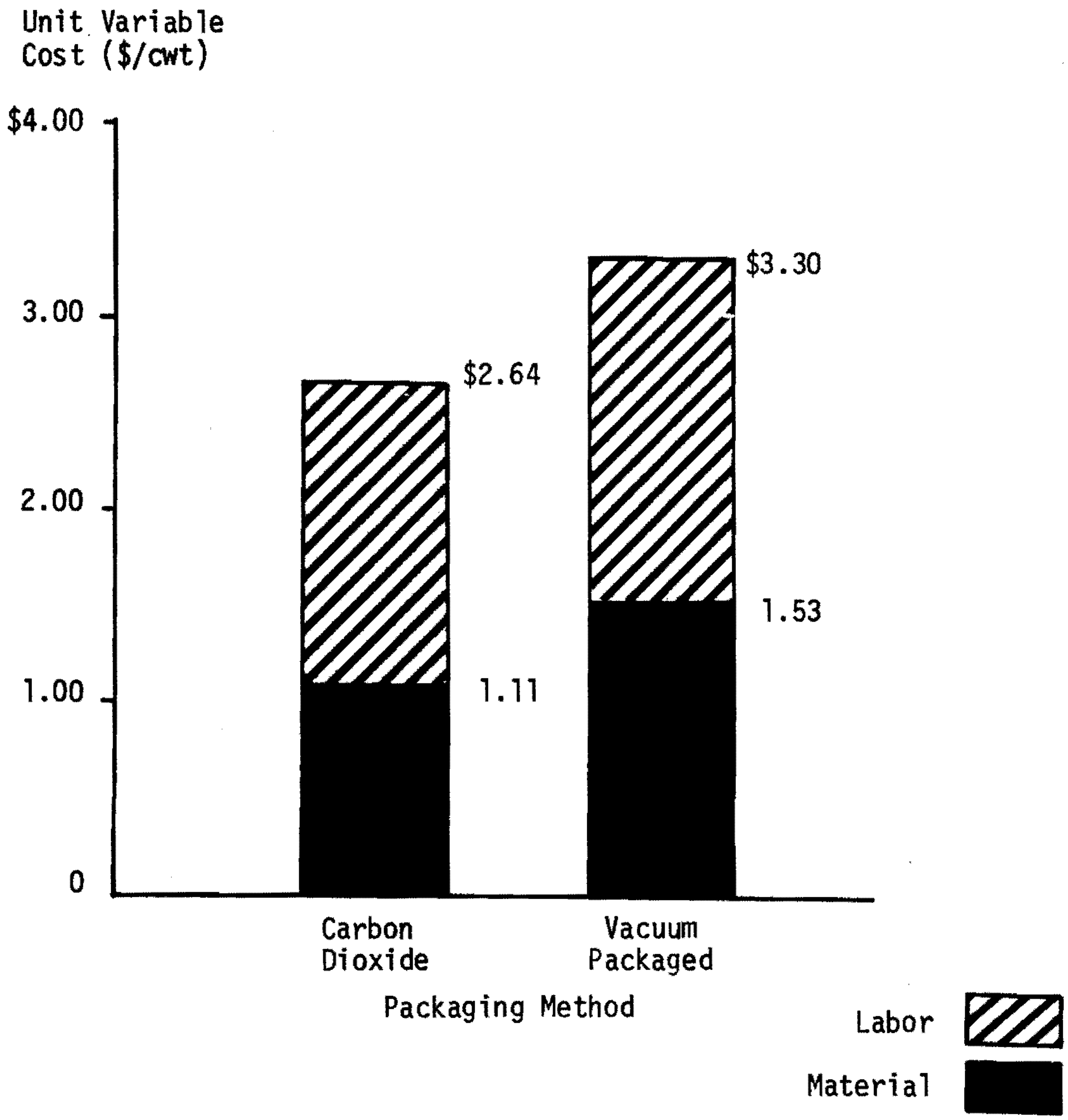

Figure 4. Unit variable cost, round subprimals

box primals, additional capital equipment is necessary but varies substantially between the carbon dioxide and vacuum packaged methods.

Annual fixed costs associated with the two methods were calculated only on the additional capital equipment necessary for the methods, exclusive of general plant overhead, or other fixed costs such as dock space or trucks.

Annual fixed costs were calculated for the carbon dioxide and vacuum packaged methods separately by depreciating each capital equipment item over its estimated useful life. Added to this depreciation is an opportunity cost on invested capital, and a percentage of initial investment for risk, insurance, and taxes. The formula for the annual fixed cost is:

$$FC_i = \frac{(I_i - S_i)}{L_i} + \left(\frac{I_i}{2}\right) r + a\, I_i$$

where

FC_i = annual fixed cost for the i^{th} capital equipment item

I_i = investment for the i^{th} capital equipment item

S_i = salvage value for the i^{th} item

L_i = total useful life in years for the i^{th} item

r = interest rate to calculate opportunity cost = 10%

a = annual allowance for risk, taxes, and insurance = 2%

For the carbon dioxide method, the only additional capital equipment items necessary were an automatic scale and miscellaneous capital equipment. The carbon dioxide pellets contained in the perforated bag were shipped in a returnable master container to the plant which cooperated in this study. Thus, no additional capital equipment was necessary for manufacturing the carbon dioxide pellets. Of course, if pellets were manufactured from carbon dioxide gas on premise then additional capital equipment would be necessary for that operation.

For the vacuum packaged method, total fixed cost was composed of cost for these capital equipment items: 1) cradles, 2) tipper ties, 3) shrink tunnel, 4) skate conveyor, 5) automatic scale, and 6) miscellaneous capital equipment items (such as hand trucks). These items represented only the additional capital equipment necessary for vacuum packaging.

Average fixed cost was calculated for ribs and rounds separately for both methods, Table 2. The average fixed cost for either method was determined at capacity of the appropriate line. Thus, the average fixed cost estimated is the low point on the average fixed cost curve. If the capital equipment necessary for either operation were operated at substantially less than capacity for long periods of time (2 years or more) actual average fixed costs would be substantially higher than those shown in Table 2.

The average fixed cost for carbon dioxide ribs was $0.014 per cwt. and $0.013 per cwt. for rounds. The vacuum packaged method average fixed cost for ribs was $0.134 per cwt. and $0.061 per cwt. for rounds.

Table 2. Unit variable, average fixed, and average total cost of carbon dioxide and vacuum packaged boxed rib and round primals.

Item	Ribs CO_2	Ribs Vacuum	Rounds CO_2	Rounds Vacuum
	($/cwt.)			
Unit Variable Cost				
Labor	0.770	1.458	1.529	1.773
Material	1.217	2.525	1.113	1.530
Total	1.987	3.983	2.642	3.303
Average Fixed Cost*	0.014	0.134	0.013	0.061
Average Total Cost*	2.001	4.117	2.655	3.364

*At capacity

Source: Primary data

Average Total Cost

Delineation of both unit variable cost and average fixed cost allows average total cost to be calculated as the sum of these two components, Table 2. Comparing unit variable cost for ribs revealed that the carbon dioxide method had unit variable costs of $1.987 per cwt. compared with $3.983 per cwt. for vacuum packaging. For rounds this same comparison was $2.642 for carbon dioxide and $3.303 for vacuum packaging.

The average total cost for carbon dioxide ribs was $2.001 per cwt. and $4.117 per cwt. for vacuum packaged ribs, Figure 5. The variable cost represented 99.3 percent of the average total cost for the carbon dioxide method. For vacuum packaged ribs, however, variable cost represented 96.7 percent of the average total cost.

For rounds, carbon dioxide average total cost was $2.655 per cwt. and $3.364 per cwt. for the vacuum packaged method, Figure 6. Thus, average total cost was composed of 99.5 percent variable cost for carbon dioxide and 98.2 percent variable cost for the vacuum packaged method.

The extremely large proportion of variable to fixed cost, as shown in Table 2, for either method indicates that neither method is capital intensive in terms of requiring substantial investment in fixed cost capital equipment. The vacuum packaged method does have a slightly higher proportion of fixed cost compared to the carbon dioxide method; however, neither requires substantial investment on a per hundredweight basis.

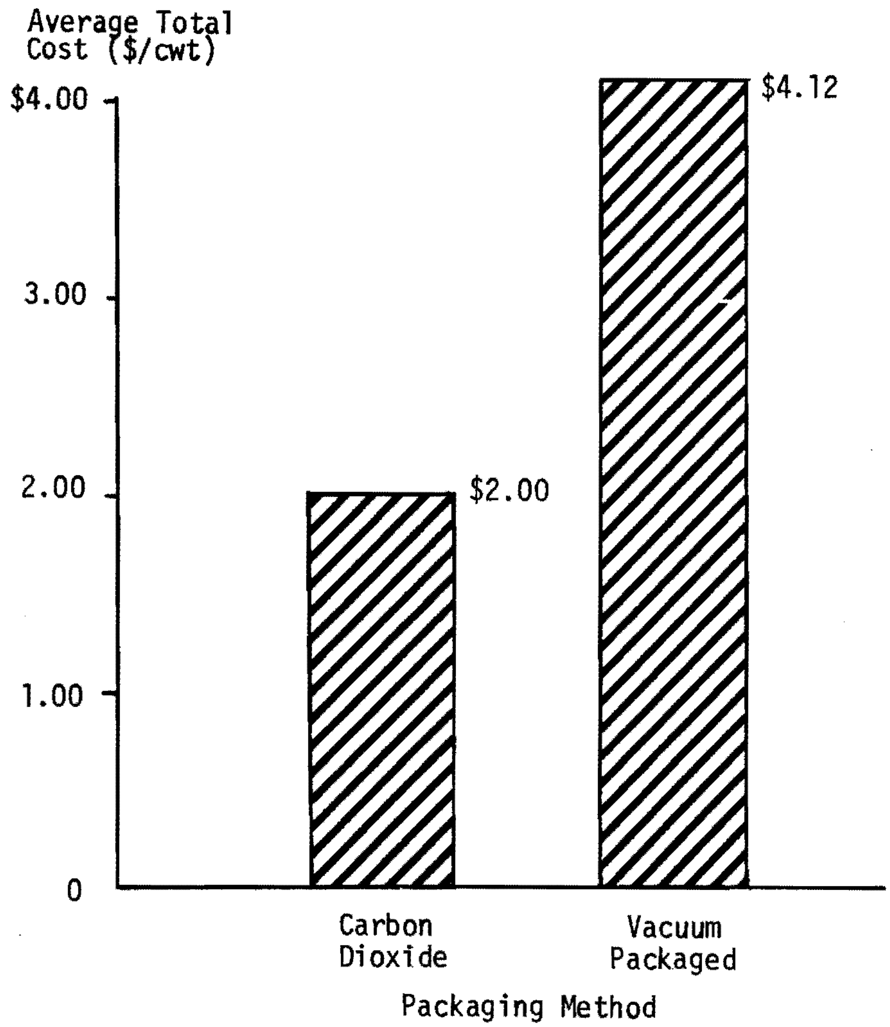

Figure 5. Average total cost, rib subprimals

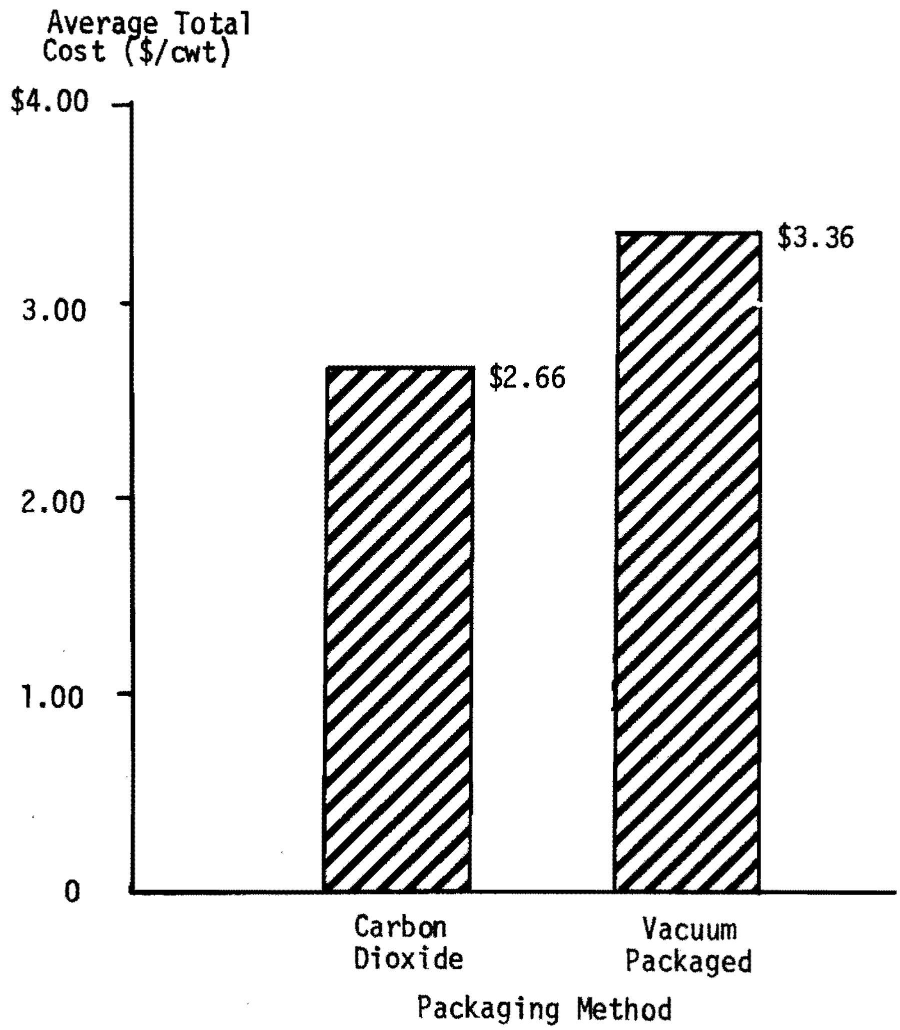

Figure 6. Average total cost, round subprimals

Comparative Net Benefits

Comparing costs associated with the two methods of packaging boxed beef would be inadequate without comparing benefits and arriving at net benefit comparisons. In comparing benefits, the subprimal must be considered as well as the retail case life of the final retail cut. Differences between the two methods of packaging boxed beef were attributed to savings in shrink, i.e. loss of weight in transit and storage including purge loss; and savings in trim loss for the subprimal. Net benefits were determined by adjusting the value of the subprimals for shrink and trim loss as well as cost of packaging. Estimated net values were based on mid-June 1973 wholesale prices of $88.50/cwt. for subprimal ribs and $80.00/cwt. for subprimal rounds. Obviously, as wholesale prices change the net value comparisons would be directly affected.

Retail case life comparisons made involve the average time cuts remain in the retail case and are considered acceptable to consumers, as well as the number of pull backs (cuts which do not meet minimum consumer acceptance). Many retail meat departments have a policy whereby a steak not sold within two days of the date it was placed on display is either pulled back, reworked, and rewrapped or reduced in price. Under this policy, the incidence of pull backs may be more important to a retail store meat department than average case life, even though they are obviously related.

There was no measurable shrink during either the 10 or 17 day transit and cooler storage periods, for either ribs or rounds in either type of package. Trim losses were determined by trained meat specialists who fabricated the subprimals into retail cuts in a manner typical for retail meat departments. In preparing the subprimals, all non-usable trim was removed and weighed to determine average trim loss. Because there was considerable variability in average trim loss among subprimals, a range in trim loss (a 95 percent confidence interval around the mean) was also determined. Thus, benefits were attributed to differences in three levels of trim loss and are presented in terms of dollars per hundredweight ($/cwt.)

Retail case life comparisons were made by comparing steaks cut from the appropriate rib or round subprimals which had been stored for 10 and 17 days respectively. One-inch thick steaks were placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film, and were displayed four days under 12 hour intervals of 80 to 100 foot candles of incandescent light. A trained panel evaluated the cuts daily to determine consumer acceptability of the steaks. The panel used an eight-point hedonic scale to visually score steaks each day for four consecutive days. These scores were used to evaluate retail case life comparisons of the two methods of packaging boxed beef. Comparisons can be made between scores of steaks after 10 days or 17 days of storage. However, comparisons between the two time periods, 10 days and 17 days of storage, should not be made due to the difficulty of assuring consistency in scoring over time.

Although a four day shelf life may exceed normal operational policy for most retail stores, this period was selected as a normal maximum within which case life comparisons should be made. The proportion of steaks considered as "steaks removed" or pull backs was determined from those steaks which received a consumer acceptability score of less than or equal to 4, "slightly undesirable." It was assumed that steaks scored undesirable by the panel would either be removed from display or reduced in price for quick sale under typical retail conditions.

Ribs

The original test shipment of vacuum packaged ribs contained 100 percent leakers, i.e. the barrier bag was torn or there was a substantial loss of vacuum. Since this condition is not typical, the 17 day day storage period was replicated under laboratory conditions. Since there was no measurable trim loss for subprimal ribs stored 10 days there was no apparent reason for replicating that phase of the research. Trained meat specialists packaged subprimal ribs with carbon dioxide pellets or vacuum packaging and stored the boxed subprimals under conditions deemed typical. Only transit could not be simulated. Retail case life comparisons were made as previously described.

The shipment test data are presented in Appendix A as Tables 3 and 4. Trim loss reductions due to the partial protection of the barrier bag were not significantly different from the carbon dioxide method (at the 0.05 level). Thus, these data revealed an advantage to the carbon dioxide method of packaging subprimal ribs. However, since it was the researcher's judgment that the 17 day replicated experiment was a more valid comparison of actual operational conditions typically observed in the industry, the replicated experimental data were used in evaluating the benefits associated with subprimal ribs stored 17 days. It should be made clear that all other data presented in this report were determined from the actual test shipment and case study analysis.

Subprimal ribs stored 10 days had no measurable trim loss, Table 3. Since the carbon dioxide method was $2.116 per cwt. less expensive than the vacuum packaged method, the latter method would have to have benefits equal to this amount to make the methods comparable.

After 17 days of storage the net wholesale value of trimmed vacuum packaged subprimals exceeded the carbon dioxide method for high, mean, and low trim losses respectively, Tables 4, 5 and 6. Thus, vacuum packaging of subprimal ribs offered a slight net advantage after 17 days of storage as the reduction in trim loss more than offset cost of packaging differences.

Table 3. Net value comparisons of 10 carbon dioxide (CO_2) and 10 vacuum packaged subprimal ribs stored 10 days

Categories	10 Days Storage		Differences
	CO_2	Vacuum	(CO_2-Vacuum)
Trim Loss (%) 1/	0.0	0.0	0.0
Wholesale Value of Trimmed Subprimal ($/cwt.) 2/	88.50	88.50	0.0
Average Total Cost of Packaging Method ($/cwt.) 2/	2.001	4.117	(-)2.116
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	86.499	84.383	(-)2.116

1/ There was no measurable trim loss for either method.

2/ Mid-June, 1973, wholesale price of $88.50 cwt. was used to estimate value.

Sources: Motycka, [3], Table 2 and calculations.

Table 4. Net value of subprimal ribs adjusted for high, mean, and low trim losses, 5 carbon dioxide subprimals, stored 17 days.

CATEGORIES	TRIM LOSS [1] HIGH	MEAN	LOW
Trim Loss (%)	3.902	3.200	2.498
Wholesale Value of Trimmed Subprimal ($/cwt.)[2]	85.047	85.668	86.289
Average Total Cost of Packaging Method ($/cwt.)	2.001	2.001	2.001
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	83.046	83.667	84.288

[1] High and low trim loss represent a 0.95 confidence interval around the mean percentage trim loss.

[2] Mid-June, 1973, wholesale price of $88.50/cwt. was used to estimate value.

Source: Motycka [3], Table 2, and calculations.

Table 5. Net value of subprimal ribs adjusted for high, mean, and low trim losses, 5 vacuum packaged subprimals, stored 17 days.

CATEGORIES	TRIM LOSS HIGH	MEAN	LOW
Trim Loss (%)	1.211	0.497	0.0
Wholesale Value of Trimmed Subprimal ($/cwt.)/2	87.438	88.060	88.5
Average Total Cost of Packaging Method ($/cwt.)	4.117	4.117	4.117
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	83.321	83.943	84.383

1\ High and low trim loss represent a 0.95 confidence interval around the mean percentage trim loss.

2\ Mid-June, 1973, wholesale price of $88.50/cwt. was used to estimate value.

Source: Motycka [3], Table 2, and calculations.

Table 6. Summary of comparisons for 5 carbon dioxide (CO_2) and 5 vacuum packaged subprimal ribs, stored 17 days 1/

Categories		Trim Loss		
		High	Mean	Low
% Trim Loss	Carbon Dioxide	3.902	3.200	2.498
	Vacuum Packaged	1.211	0.497	0.0
	CO_2 - Vacuum 4/	2.691	2.703	2.498
Net Wholesale Value (\$/cwt) 2/	Carbon Dioxide	83.046	83.667	84.288
	Vacuum Packaged	83.321	83.943	84.383
	CO_2 - Vacuum 4/	(-)0.276	(-)0.276	(-)0.095
Net Wholesale Value as % of Mid-June Price 3/	Carbon Dioxide	93.837	94.539	95.240
	Vacuum Packaged	94.148	94.851	95.348
	CO_2 - Vacuum 4/	(-)0.311	(-)0.312	(-)0.108

1/ Data are from replicated experiment. Original test data are presented in Appendix A.

2/ Net wholesale value of trimmed packaged subprimal adjusted for packaging costs of \$2.001/cwt. for carbon dioxide and \$4.117/cwt. for vacuum packaged.

3/ Mid-June price of \$88.50/cwt. was assumed.

4/ CO_2 minus vacuum packaging.

Source: Tables 4 and 5.

Retail case life scores of steaks from subprimals stored 10 days for the two methods were essentially the same, Table 7. However, steaks from 17 day subprimals received statistically significant higher consumer acceptance scores for vacuum packaging after the first day. Since the average scores exceeded the minimum acceptable level except for the fourth day for carbon dioxide, the statistical significance may have little meaning until the fourth day. One might argue that higher consumer acceptability scores would reflect increased merchandising opportunities but no evidence can be presented to that effect. However, the incidence of "steaks removed" for the carbon dioxide method was one of five for the third and three of five for the fourth day compared to none for vacuum packaging.

Rounds

The net value of subprimal rounds adjusted for trim loss was greater for vacuum packaging at both the 10 and 17 day comparisons, Tables 8 - 13. Thus, without considering the advantages in retail case life, the vacuum packaged method was determined to offer an advantage over the carbon dioxide method of packaging boxed beef. After 10 days of storage, vacuum packaging represented an increased net value of 0.08 percent, 0.27 percent, and 0.42 percent for high, mean, and low trim losses respectively, Table 10.

After 17 days of storage the difference was greater, Table 13. The respectively higher net value differences for high, mean, and low trim loss levels represented advantages for vacuum packaging of 3.17

Table 7. Retail case life comparisons of rib steaks from 10 carbon dioxide and 10 vacuum packaged subprimals, stored 10 and 17 days 1/

Days of Retail Case Life	Stored 10 days: CO_2 Consumer Acceptance[2]	Stored 10 days: CO_2 Steaks Removed[3]	Stored 10 days: Vacuum Consumer Acceptance	Stored 10 days: Vacuum Steaks Removed	Stored 17 days: CO_2 Consumer Acceptance	Stored 17 days: CO_2 Steaks Removed	Stored 17 days: Vacuum Consumer Acceptance	Stored 17 days: Vacuum Steaks Removed
1	7.40	0	7.45	0	7.00	0	7.80	0
2	7.16	0	7.16	0	6.27[x]	0	7.67[x]	0
3[4]	7.03	0	6.80	0	4.87[x]	1	7.07[x]	0
4	6.66	1	6.53	1	3.67[x]	3	6.33[x]	0

1 17 day ribs from 5 carbon dioxide and 5 vacuum packaged subprimals.

2 Consumer acceptance based on 8 point hedonic scale (8= extremely desirable, 4 = slightly undesirable, 1 = extremely undesirable).

3 Steaks removed = the number of steaks tested which received a consumer acceptance score ≤ 4. It was judged that they would not normally be offered for sale by a retailer at regular price.

4 A short term increase in temperature occurred for the retail cuts between the 2nd and 3rd days for the 10 day ribs. Thus, comparisons between 10 and 17 days should not be made.

x CO_2 and vacuum were significantly different at 0.05 level.

Sources: Motycka [3].

Table 8. Net value of subprimal rounds adjusted for trim loss, 10 carbon dioxide subprimals, stored 10 days.

CATEGORY	TRIM LOSS[1] HIGH	MEAN	LOW
Trim Loss (%)	1.551	1.428	1.304
Wholesale Value of Trimmed Subprimal ($/cwt.)	78.759	78.858	78.957
Average Total Cost of Packaging Method ($/cwt.)	2.655	2.655	2.655
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	76.104	76.203	76.302

1 High and low trim loss represent a 0.95 confidence interval around the mean percentage trim loss.

2 Mid-June, 1973, wholesale price of $80.00/cwt. was used to estimate value.

Source: Motycka [3], Table 2, and calculations.

Table 9. Net value of subprimal rounds adjusted for trim loss, 10 vacuum packaged subprimals, stored 10 days.

CATEGORIES	TRIM LOSS [1] HIGH	MEAN	LOW
Trim Loss (%)	0.582	0.274	0
Wholesale Value of Trimmed Subprimal ($/cwt.) [2]	79.535	79.781	80.00
Average Total Cost of Packaging Method ($/cwt.)	3.364	3.364	3.364
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	76.171	76.417	76.636

[1] High and low trim loss represent a 0.95 confidence interval around the mean percentage trim loss.

[2] Mid-June, 1973, wholesale price of $80.00/cwt. was used to estimate value.

Source: Motycka [3], Table 2, and calculations.

Table 10. Summary of comparisons for 10 carbon dioxide (CO_2) and 10 vacuum packaged subprimal rounds; stored 10 days

Categories		Trim Loss High	Trim Loss Mean	Trim Loss Low
% Trim Loss	Carbon Dioxide	1.551	1.428	1.304
	Vacuum Packaged	0.582	0.274	0.0
	CO_2 - Vacuum	0.969	1.155	1.304
Net Wholesale Value ($/cwt.)1/	Carbon Dioxide	76.1042	76.203	76.302
	Vacuum Packaged	76.171	76.417	76.636
	CO_2 - Vacuum	(-)0.067	(-)0.214	(-)0.334
Net Wholesale Value as % of Mid-June Price2/	Carbon Dioxide	95.130	95.253	95.377
	Vacuum Packaged	95.213	95.521	95.795
	CO_2 - Vacuum	(-)0.083	(-)0.268	(-)0.418

1/Net wholesale value of trimmed packaged subprimal adjusted for packaging costs of $2.655/cwt. for carbon dioxide and $3.364/cwt. vacuum packaging.

2/Mid-June wholesale price of $80.00/cwt. was assumed.

Source: Tables 8 and 9.

Table 11. Net value of subprimal rounds adjusted for trim loss, 10 carbon dioxide subprimals, stored 17 days.

CATEGORIES	TRIM LOSS [1] HIGH	MEAN	LOW
Trim Loss (%)	4.694	3.923	3.151
Wholesale Value of Trimmed Subprimal ($/cwt.) [2]	76.245	76.862	77.479
Average Total Cost of Packaging Method ($/cwt.)	2.655	2.655	2.655
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	73.590	74.207	74.824

[1] High and low trim loss represent a 0.95 confidence interval around the mean percentage trim loss.

[2] Mid-June, 1973, wholesale price of $80.00/cwt. was used to estimate value.

Source: Motycka [3], Table 2, and calculations.

Table 12. Net value of subprimal rounds adjusted for trim loss, 10 vacuum packaged subprimals, stored 17 days.

CATEGORIES	TRIM LOSS [1] HIGH	MEAN	LOW
Trim Loss (%)	0.642	0.197	0
Wholesale Value of Trimmed Subprimal ($/cwt.) [2]	79.486	79.842	80.00
Average Total Cost of Packaging Method ($/cwt.)	3.364	3.364	3.364
Net Wholesale Value of Trimmed Packaged Subprimal ($/cwt.)	76.122	76.478	76.636

[1] High and low trim loss represent a 0.95 confidence interval around the mean percentage trim loss.

[2] Mid-June, 1973, wholesale price of $80.00/cwt. was used to estimate value.

Source: Motycka [3], Table 2, and calculations.

Table 13. Summary of comparisons for 10 carbon dioxide (CO_2) and 10 vacuum packaged subprimal rounds, stored 17 days

Categories		Trim Loss High	Trim Loss Mean	Trim Loss Low
% Trim Loss	Carbon Dioxide	4.694	3.923	3.151
	Vacuum Packaged	0.642	0.197	0.0
	CO_2 - Vacuum	4.052	3.726	3.151
Net Wholesale Value ($/cwt.) 1/	Carbon Dioxide	73.590	74.207	74.824
	Vacuum Packaged	76.122	76.478	76.636
	CO_2 - Vacuum Pac	(-)2.532	(-)2.271	(-)1.812
Net Wholesale Value as % of Mid-June Price 2/	Carbon Dioxide	91.987	92.758	93.530
	Vacuum Packaged	95.153	95.598	95.795
	CO_2 - Vacuum	(-)3.166	(-)2.840	(-)2.265

1/ Net wholesale value of trimmed packaged subprimal adjusted for packaging costs of $2.655/cwt. for carbon dioxide and $3.364/cwt. for vacuum packaging.

2/ Mid-June wholesale price of $80.00/cwt. was assumed.

Source: Tables 4 and 12.

percent, 2.84 percent, and 2.26 percent. Thus, the savings in trim loss realized by the vacuum packaged method exceeded the increased cost of the method resulting in a net savings to vacuum packaging. As storage time for the subprimals was increased the savings from vacuum packaging increased.

Steaks from the inside and outside round were cut from subprimals stored for both 10 and 17 days. Inside round steaks from both methods received average consumer acceptance scores which were considered desirable until the fourth day of display for the 10 day carbon dioxide method, Table 14.

A short increase in retail case temperature was experienced between the second and third day of display, which probably accounted for the higher incidence of steaks removed as well as the relatively lower consumer acceptance scores between the two time periods. Although this was an unexpected occurrence it does illustrate the importance of temperature control. The carbon dioxide method for 10 days of storage had 30 percent and 40 percent greater incidence of steaks receiving undesirable consumer acceptance scores during the third and fourth days of display, Table 14. Observed differences in incidence of steaks receiving undesirable scores was not as apparent for those subprimals stored 17 days. Ten percent more steaks were removed for carbon dioxide on the fourth day only.

Retail case life comparisons for steaks taken from the outside round subprimals stored 10 and 17 days were almost identical to those made for the inside round steaks. The incidence of steaks receiving undesirable scores for carbon dioxide was greater than for vacuum packaging except

Table 14. Retail case life comparisons of inside round steaks from 10 carbon dioxide and 10 vacuum packaged subprimals, stored 10 and 17 days

	10 Day Storage				17 Day Storage			
	CO_2		Vac Pac		CO_2		Vac Pac	
Days of Retail Case Life	Consumer Acceptance[1]	Steaks Removed[2]	Consumer Acceptance	Steaks Removed	Consumer Acceptance	Steaks Removed	Consumer Acceptance	Steaks Removed
1	6.25	0	6.30	0	6.95	0	7.40	0
2	4.93	2	5.20	0	6.13	0	6.76	0
3[3]	4.00[x]	5	4.86[x]	2	5.06[x]	1	6.30[x]	1
4	3.73[x]	7	4.53[x]	3	4.16[x]	3	4.70[x]	2

1 Consumer acceptance based on 8 point hedonic scale (8 = extremely desirable, 4 = slightly undesirable, 1 = extremely undesirable)

2 Steaks Removed = the number of steaks tested which received a consumer acceptance score ≤ 4. It was judged that they would not normally be offered for sale by a retailer at regular price.

3 A short term increase in temperature occurred for the retail cuts between the 2nd and 3rd days for the 10 day steaks. Thus, comparisons between 10 and 17 days should not be made.

x CO_2 and vacuum packaging were significantly different at 0.05 level.

Source: Motycka [3].

Table 15. Retail case life comparisons of outside round steaks from 10 carbon dioxide and 10 vacuum packaged subprimals, stored 10 and 17 days

Days of Retail Case Life	10 DAYS				17 DAYS			
	CO_2		Vac Pac		CO_2		Vac Pac	
	Consumer Acceptance[1]	Steaks Removed[2]	Consumer Acceptance	Steaks Removed	Consumer Acceptance	Steaks Removed	Consumer Acceptance	Steaks Removed
1	7.00	0	6.80	0	7.40	0	7.65	0
2	5.20	2	5.86	0	6.23	0	6.80	0
3[3]	4.40	5	4.76	1	5.43	2	6.26	1
4	3.66[xx]	9	4.60[xx]	2	4.16	4	4.53	4

[1] Consumer acceptance based on 8 point hedonic scale (8 = extremely desirable, 4 = slightly undesirable, 1 = extremely undesirable).

[2] Steaks removed = the number of steaks tested which received a consumer acceptance score ≤ 4. It was judged that they would not normally be offered for sale by a retailer at regular price.

[3] A short term increase in temperature occurred for the retail cuts between the 2nd and 3rd days for the 10-day steaks. Thus, comparisons between 10 and 17 days should not be made.

[xx] CO_2 and vacuum packaging were significantly different at the 0.01 level.

Source: Motycka [3].

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APPENDIX A

Summary of selected data for certain traits of subprimals and steaks from subprimals, carbon dioxide chill versus vacuum packaged stored 10 and 17 days, 1973.

Table 1. Means and standard deviations for certain traits of subprimal ribs stored 10 days.

Traits	Carbon Dioxide Chill[a]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Fat color[b]	10	4.13^{h}	0.68	10	3.73^{h}	0.76
Muscle color (longissimus dorsi)[c]	10	6.50^{h}	0.91	10	5.66^{h}	1.09
Odor[d]	10	3.60^{j}	0.49	10	3.06^{k}	0.26
Surface discoloration (longissimus dorsi)[e]	10	4.56^{j}	1.07	10	3.30^{k}	0.77
Overall acceptance[f]	10	5.70^{h}	1.21	10	4.76^{i}	0.62
Bacteria count prior to storage ($\log_{10}/2in^2$)	2	2.21^{h}	0.61	3	2.28^{h}	0.28
Bacteria count after storage ($\log_{10}/2in^2$	5	5.41^{h}	0.61	5	4.90^{h}	0.54
Vacuum package condition[g]	--	--	--	10	2.00	0.64

[a]2 lbs. of carbon dioxide pellets per 2 subprimal ribs packaged in a polyethylene bag lined cardboard box.

[b]Means based on a 6-point scale (6 = very fresh; 1 = extensive discoloration).

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[g]Means based on a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[hi]Means bearing different superscripts differ significantly ($P < .05$).

[jk]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 2. Means and standard deviations for certain traits of rib steaks[a] from subprimal ribs stored 10 days.

Traits	Carbon Dioxide Chill[c]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Initial muscle color[c]	10	5.56[g]	0.83	10	5.90[g]	0.83
Shrinkage (%)	10	0.87[g]	0.01	10	0.60[g]	0.36
Odor[d]	9	2.18[g]	0.52	9	2.22[g]	0.37
Bacteria count prior to display ($\log_{10}/2in^2$)	5	3.46[g]	0.00	5	3.60[g]	0.32
Bacteria count after display ($\log_{10}/2in^2$)	5	5.48[g]	0.99	5	5.29[g]	1.75
Surface discoloration - day 1[e]	10	6.70[g]	0.34	10	6.85[g]	0.24
Surface discoloration - day 2	10	6.43[g]	0.31	10	6.53[g]	0.35
Surface discoloration - day 3[f]	10	6.43[g]	0.47	10	6.43[g]	0.52
Surface discoloration - day 4	10	6.23[g]	0.70	10	6.20[g]	0.95
Consumer acceptance - day 1	10	7.40[g]	0.45	10	7.45[g]	0.59
Consumer acceptance - day 2	10	7.16[g]	0.45	10	7.16[g]	0.47
Consumer acceptance - day 3	10	7.03[g]	0.93	10	6.80[g]	0.98
Consumer acceptance - day 4	10	6.66[g]	1.15	10	6.53[g]	1.31

[a]1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film, and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b]2 lbs of carbon dioxide pellets per 2 subprimal ribs packaged in a polyethylene bag lined cardboard box.

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[g]Mean values were not significantly different.

Source: Motycka [3].

Table 3. Means and standard deviations for certain traits of subprimal ribs stored 17 days.

Traits	Carbon Dioxide Chill[a]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Fat color [b]	10	4.16[j]	0.57	10	3.10[k]	0.58
Muscle color (longissimus dorsi)[c]	2	6.33[h]	0.47	Too discolored to score		
Odor[d]	10	2.13[h]	0.35	10	2.13[h]	0.35
Surface discoloration (longissimus dorsi)[e]	10	2.80[h]	0.87	10	2.26[h]	0.21
Overall acceptance[f]	10	4.16[h]	0.57	10	4.60[h]	0.68
Bacteria count prior to storage ($\log_{10}/2in^2$)	3	1.06[h]	1.08	2	2.75[h]	0.13
Bacteria count after storage ($\log_{10}/2in^2$)	5	7.21[h]	0.58	5	5.87[i]	1.03
Vacuum package condition[g]	--	--	--	10	1.73	0.64
Nonusable trim (lbs.)	10	0.58[h]	0.14	10	0.49[h]	0.09

[a]2 lbs. of carbon dioxide pellets per 2 subprimal ribs packaged in a polyethylene bag lined cardboard box.

[b]Means based on a 6-point scale (6 = very fresh; 1 = extensive discoloration).

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[g]Means based on a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[hi]Means bearing different superscripts differ significantly ($P < .05$).

[jk]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 3a. Means and standard deviations for certain traits of subprimal ribs stored 17 days, replicated experiment.

Traits	Carbon Dioxide Chill[a]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Fat color[b]	25	2.986667[g]	1.006829	25	2.826667[g]	0.981873
Odor[c]	25	2.413333[g]	1.094092	25	3.240000[h]	0.557109
Surface discoloration (longissimus dorsi)[d]	25	3.240[g]	1.184467	25	4.240000[h]	0.988452
Overall acceptance[e]	25	3.013333[i]	1.060573	25	5.813333[j]	1.427508
Bacteria count prior to storage ($\log_{10}/2in^2$)	5	5.26534[g]	1.795428	5	4.526980[g]	0.144405
Bacteria count after storage ($\log_{10}/2in^2$)	5	13.5604[g]	2.743072	5	8.410080[h]	1.012444
Vacuum package condition[f]	--	--	--	25	2.826667	0.981873
Nonusable trim (lbs.)	25	0.360[i]	0.160364	25	0.0316[j]	0.066688

[a]2 lbs. of carbon dioxide pellets per 2 subprimal ribs packaged in a polyethylene bag lined cardboard box.

[b]Means based on a 6-point scale (6 = very fresh; 1 = extensive discoloration).

[c]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[d]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[e]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[f]Means based on a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[gh]Means bearing different superscripts differ significantly ($P < .05$).

[ij]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 4. Means and standard deviations for certain traits of rib steaks[a] from subprimal ribs store 17 days.

Traits	Carbon Dioxide Chill[b]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Initial muscle color[c]	10	6.36[j]	0.42	10	6.50[j]	0.57
Shrinkage (%)	10	0.52[g]	0.01	10	0.83[g]	0.67
Odor[d]	9	2.07[g]	0.40	10	2.40[g]	0.46
Bacteria count prior to display ($\log_{10}/2in^2$)	--	--	--	--	--	--
Bacteria count after display ($\log_{10}/2in^2$)	5	5.62[g]	1.04	5	4.71[g]	0.25
Surface discoloration - day 1[e]	10	6.70[g]	0.25	10	7.00[h]	0.00
Surface discoloration - day 2	10	6.80[g]	0.17	10	6.96[g]	0.10
Surface discoloration - day 3	10	6.60[g]	0.26	10	6.76[g]	0.22
Surface discoloration - day 4	10	5.90[g]	0.27	10	6.30[h]	0.36
Consumer acceptance - day 1[f]	10	7.85[g]	0.24	10	7.80[g]	0.25
Consumer acceptance - day 2	10	7.73[g]	0.26	10	7.86[g]	0.17
Consumer acceptance - day 3	10	7.46[g]	0.17	10	7.66[g]	0.38
Consumer acceptance - day 4	10	5.73[g]	0.75	10	6.60[h]	0.62

[a] 1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 guage polyvinyl chloride film, and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b] 2 lbs. of carbon dioxide pellets per 2 subprimal ribs packaged in a polyethylene bag in a cardboard box.

Table 4 (continued)

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[gh]Means bearing different superscripts differ significantly ($P < .05$).

[ij]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 4a. Means and standard deviations for certain traits of rib steaks[a] from subprimal ribs stored 17 days, replicated experiment.

Traits	Carbon Dioxide Chill[b]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Surface discoloration - day 1[c]	55	6.466667[e]	0.505525	5	7.000000[f]	0.0
Surface discoloration - day 2	5	5.866667[e]	0.960324	5	6.933333[f]	0.149071
Surface discoloration - day 3	5	4.933333[g]	1.011050	5	6.866667[h]	0.182574
Surface discoloration - day 4	5	3.666667[g]	1.054093	5	6.400000[h]	0.278887
Consumer acceptance - day 1[d]	5	7.000000[e]	1.154701	5	7.800000[f]	0.298142
Consumer acceptance - day 2	5	6.266667[e]	1.233784	5	7.666667[f]	0.235702
Consumer acceptance - day 3	5	4.866667[g]	1.069787	5	7.066667[h]	0.722649
Consumer acceptance - day 4	5	3.666667[g]	1.054093	5	6.333333[h]	0.816497

[a]1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film, and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b]2 lbs. of carbon dioxide pellets per 2 subprimal ribs packaged in a polyethylene bag in a cardboard box.

[c]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% discoloration).

[d]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[ef]Means bearing different superscripts differ significantly ($P < .05$).

[gh]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 5. Means and standard deviations for certain traits of subprimal rounds stored 10 days.

Traits	Carbon Dioxide Chill[a]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Fat color[b]	10	3.86[h]	0.35	10	4.00[h]	0.70
Muscle color (sirloin surface)[c]	Too discolored to score.			10	6.53	0.81
Odor[d]	10	2.30[h]	0.61	10	3.13[i]	0.90
Surface discoloration (sirloin surface)[e]	10	2.50[j]	0.52	10	4.76[k]	1.99
Overall acceptance[f]	10	3.76[j]	0.49	10	6.40[k]	1.83
Bacteria count prior to storage ($\log_{10}/2in^2$)	2	1.34	1.89	--	--	--
Bacteria count after storage ($\log_{10}/2in^2$)	5	7.34[j]	0.20	5	4.63[k]	0.31
Vacuum package condition[g]	--	--	--	10	3.10	1.32
Nonusable trim (lbs.)	10	0.83[j]	0.13	10	0.16[k]	0.25

[a]2 lbs. of carbon dioxide pellets per round packaged in a polyethylene bag lined cardboard box.

[b]Means based on a 6-point scale (6 = very fresh; 1 = extensive discoloration).

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[g]Means based on a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[hi]Means bearing different superscripts differ significantly (P < .05).

[jk]Means bearing different superscripts differ significantly (P < .01).

Source: Motycka [3].

Table 6. Means and standard deviations for certain traits of inside round steaks[a] from subprimal rounds stored 10 days.

Traits	Carbon Dioxide Chill[b]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Initial muscle color[c]	10	5.40[g]	0.69	10	5.30[g]	0.67
Shrinkage (%)	10	1.22[i]	0.38	10	0.67[j]	0.09
Odor[d]	Not evaluated due to low C.A. 4d.			4	2.83	0.64
Bacteria count prior to display ($\log_{10}/2in^2$)	5	4.10[g]	0.91	5	3.49[g]	0.08
Bacteria count after display ($\log_{10}/2in^2$)	5	7.10[i]	0.62	5	5.92[j]	0.39
Surface discoloration - day 1[e]	10	5.95[g]	0.55	10	5.85[g]	0.33
Surface discoloration - day 2	10	4.43[g]	0.78	10	4.90[g]	0.66
Surface discoloration - day 3	10	3.93[g]	0.75	10	4.56[g]	0.60
Surface discoloration - day 4	10	3.93[g]	0.87	10	3.83[g]	0.59
Consumer acceptance - day 1[f]	10-0	6.25[g]	0.26	10-0	6.30[g]	0.48
Consumer acceptance - day 2	10-2	4.93[g]	0.88	10-0	5.20[g]	0.65
Consumer acceptance - day 3	10-5	4.00[g]	0.73	10-2	4.86[h]	0.72
Consumer acceptance - day 4	10-6	3.73[g]	0.78	10-3	4.53[h]	0.84

C.A. 4d. = Consumer acceptance on day 4 was below the score of 4 (slightly undesirable).

[a]1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b]2 lbs. of carbon dioxide pellets per subprimal round packaged in a polyethylene bag lined cardboard box.

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

Table 6 (continued)

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 - no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[gh]Means bearing different superscripts differ significantly ($P < .05$).

[ij]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 7. Means and standard deviations for certain traits of outside round steaks[a] from subprimal rounds stored 10 days.

Traits	Carbon Dioxide Chill[b]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Initial muscle color[c]	10	6.30[h]	0.48	10	6.00[h]	0.66
Shrinkage (%)	10	0.95[h]	0.17	10	0.87[h]	0.15
Odor[d]	Not evaluated due to low C.S. 4d.			4	2.83	1.73
Bacteria count prior to display $(\log_{10}/2in^2)$[e]	5	4.10[h]	0.91	5	3.49[h]	0.08
Bacteria count after display $(\log_{10}/2in^2)$[e]	5	7.10[h]	0.62	5	5.92[i]	0.39
Surface discoloration - day 1[f]	10	6.30[h]	0.34	10	6.45[h]	0.55
Surface discoloration - day 2	10	4.83[h]	0.77	10	5.33[h]	0.44
Surface discoloration - day 3	10	4.33[h]	0.56	10	4.36[h]	0.39
Surface discoloration - day 4	10	3.90[h]	0.54	10	3.90[h]	0.47
Consumer acceptance - day 1[g]	10	7.00[h]	0.47	10	6.80[h]	0.63
Consumer acceptance - day 2	10	5.20[h]	0.91	10	5.86[h]	0.61
Consumer acceptance - day 3	10	4.40[h]	0.69	10	4.76[h]	0.56
Consumer acceptance - day 4	10	3.66[h]	0.52	10	4.60[i]	0.51

C.A. 4d. = Consumer acceptance on day 4 was below the score 4 (slightly undesirable).

[a]1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film, and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b]2 lbs. of carbon dioxide pellets per subprimal round packaged in a polyethylene bag lined cardboard box.

Table 7 (continued)

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Samples from steaks of the round, no differentiation made concerning type of steak sampled.

[f]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[g]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undrsirable).

[hi]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 8. Means and standard deviations for certain traits of subprimal rounds stored 17 days.

Traits	Carbon Dioxide Chill[a]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Fat color[b]	10	2.16^{h}	0.59	10	3.83^{i}	0.93
Muscle color (sirloin surface)[c]	Too discolored to score.			10	6.70	0.48
Odor[d]	10	1.40^{h}	0.40	10	3.16^{i}	0.77
Surface discoloration (sirloin surface)[e]	10	1.96^{h}	0.39	10	5.13^{i}	1.63
Overall acceptance[f]	10	3.16^{h}	0.63	10	5.96^{i}	1.05
Bacteria count prior to storage ($\log_{10}/2in^2$	2	2.69	0.08	--	--	--
Bacteria count after storage ($\log_{10}/2in^2$)	5	7.42^{h}	0.12	5	5.82^{i}	0.37
Vacuum package condition[g]	--	--	--	10	3.16	0.77
Nonusable trim (lbs.)	10	1.96^{h}	0.39	10	0.18^{i}	0.33

[a]2 lbs. of carbon dioxide pellets per round packaged in a polyethylene bag lined cardboard box.

[b]Means based on a 6-point scale (6 = very fresh; 1 = extensive discoloration).

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[g]Means based on a 4-point scale (4 = complete vacuum; 1 = vacuum lost).

[hi]Means bearing different superscripts differ significantly ($P < .01$).

Source: Motycka [3].

Table 9. Means and standard deviations for certain traits of inside round steaks[a] from subprimal rounds stored 17 days.

Traits	Carbon Dioxide Chill[b]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Initial muscle color[c]	10	6.40[g]	0.51	10	5.90[g]	0.87
Shrinkage (%)	10	2.32[g]	0.13	10	2.36[g]	0.22
Odor[d]	Not evaluated due to low C.A. 4d.			10	3.45	1.67
Bacteria count prior to display ($\log_{10}/2in^2$)	--	--	--	--	--	--
Bacteria count after display ($\log_{10}/2in^2$)	5	5.89[g]	1.01	5	6.35[g]	1.42
Surface discoloration - day 1[e]	10	6.15[g]	0.41	10	6.35[g]	0.33
Surface discoloration - day 2	10	5.66[g]	0.80	10	6.06[g]	0.53
Surface discoloration - day 3	10	5.23[g]	0.95	10	5.63[g]	0.48
Surface discoloration - day 4	10	4.23[g]	0.96	10	4.43[g]	1.04
Consumer acceptance - day 1[f]	10	6.95[g]	0.64	10	7.40[g]	0.39
Consumer acceptance - day 2	10	6.13[g]	0.84	10	6.76[g]	0.56
Consumer acceptance - day 3	10	5.06[g]	1.06	10	6.30[h]	0.89
Consumer acceptance - day 4	10	4.16[g]	0.95	10	4.70[h]	1.34

C.A. 4d. = Consumer acceptance on day 4 was below the score of 4 (slightly undesirable).

[a]1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film, and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b]2 lbs. of carbon dioxide pellets per subprimal round packaged in a polyethylene bag lined cardboard box.

Table 9 (continued)

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[f]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[gh]Means bearing different superscripts differ significantly ($P < .05$).

Source: Motycka [3].

Table 10. Means and standard deviations for certain traits of outside round steaks[a] from subprimal rounds stored 17 days.

Traits	Carbon Dioxide Chill[b]			Vacuum Package		
	n	Mean	S.D.	n	Mean	S.D.
Initial muscle color[c]	10	7.00^{h}	0.81	10	7.10^{h}	0.87
Shrinkage (%)	10	2.33^{h}	--	10	1.42^{i}	--
Odor[d]	3	6.66	0.57	4	8.75	2.06
Bacteria count prior to display ($\log_{10}/2in^2$)	--	--	--	--	--	--
Bacteria count after display ($\log_{10}/2in^2$)[e]	5	5.89^{h}	2.01	5	6.35^{h}	1.42
Surface discoloration - day 1[f]	10	6.45^{h}	0.49	10	6.55^{h}	0.49
Surface discoloration - day 2	10	6.06^{h}	0.68	10	6.13^{h}	0.42
Surface discoloration - day 3	10	5.36^{h}	1.02	10	5.73^{h}	0.49
Surface discoloration - day 4	10	4.13^{h}	1.18	10	4.23^{h}	1.19
Consumer acceptance - day 1[g]	10	7.40^{h}	0.45	10	7.65^{h}	0.41
Consumer acceptance - day 2	10	6.23^{h}	1.08	10	6.80^{h}	0.61
Consumer acceptance - day 3	10	5.43^{h}	1.37	10	6.26^{h}	1.14
Consumer acceptance - day 4	10	4.16^{h}	1.04	10	4.53^{h}	1.57

[a]1 inch thick steaks placed on a styrofoam backing board, wrapped with 50 gauge polyvinyl chloride film and displayed 4 days under 12 hour intervals of 82 foot candles of incandescent light.

[b]2 lbs. of carbon dioxide pellets per subprimal round packaged in a polyethylene bag lined cardboard box.

Table 10 (continued)

[c]Means based on a 9-point scale (9 = very light cherry red; 5 = slightly dark red; 1 = black).

[d]Means based on a 4-point scale (4 = no detectable off odor; 1 = extreme detectable off odor).

[e]Samples from steaks of the round, no differentiation made concerning type of steaks sampled.

[f]Means based on a 7-point scale (7 = no discoloration; 1 = 75 to 100% green discoloration).

[g]Means based on an 8-point scale (8 = extremely desirable; 4 = slightly undesirable; 1 = extremely undesirable).

[hi]Means bearing different superscripts differ significantly ($P < .05$).

Source: Motycka [3].