

Proceedings of the Tenth Annual Tropical and Subtropical Fisheries Conference of the Americas



Including Index of
Volumes 1-10

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PROCEEDINGS OF THE TENTH ANNUAL
TROPICAL AND SUBTROPICAL FISHERIES CONFERENCE
OF THE AMERICAS

Compiled by
Donn R. Ward
Granvil D. Treece
Including Index of Volumes 1-10

The Tropical and Subtropical Fisheries Technological Society of the Americas is a professional and educational association of fishery technologists interested in the application of science to the unique problems of production, processing, packaging, distribution and utilization of tropical and subtropical fishery species.

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IN MEMORY

Melvin E. Waters
April 7, 1928 - August 15, 1984
Research Food Technologist

This issue of these proceedings is dedicated to Melvin E. Waters. Melvin Waters was a practical "hands-on" food technologist whose research and services benefited all associated with seafood processing. His early research centered with resolving complex problems dealing with traditional species such as blueing of crabmeat and iron sulfide discoloration in canned shrimp. Next he addressed the myriad of processing opportunities for underutilized species in the Gulf and South Atlantic such as thread herring, speckled and white trout, redfish, croaker, and spanish mackerel, and finally he was instrumental in introducing minced fish technology into the region. The results and practical application from this effort are legion. All in all, Melvin had over 100 publications and technical presentations dealing with various aspects of seafood technology. He was always willing to address any new problem as an opportunity for the seafood industry and was instrumental in the formation of this conference.

It is hoped that his professionalism, enthusiasm, and ability shown to the seafood industry will be an inspiration for the new generation of younger food technologists who begin to follow in his path.

TENTH ANNUAL TROPICAL AND SUBTROPICAL FISHERIES TECHNICAL
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PROCESSING COSTS AND VALUE ADDED IN THE
GULF SHRIMP INDUSTRY, 1982

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INTRODUCTION

Objectives

The objective of this study was to collect and analyze statistical data required to assess the value added through processing and consequently the economic contribution of shrimp harvested and processed in the Gulf of Mexico.

Economic studies of shrimp processing and marketing have assumed that the processing, wholesale and retail margins are similar for all seafood species. Margins for shrimp may vary considerably from those of other seafood products, and may vary depending on the final form and market outlet for the finished product.

Background

Seafood is big business in the United States. The dockside value of all fisheries is consistently more than \$2 billion a year. In 1982, it was \$2,237.29 million and in 1983, \$2,355.45 million. In 1982, the United States imported \$4,523.57 million worth, or 49 percent of all fishery products consumed. By 1983, imports had expanded to \$5,129.31 million, for 46 percent of total consumption. Importation of fishery products accounted for 10 percent of the national deficit in trade for 1982 and slightly over 2 percent in 1983.

The shrimp fishery is the most valuable of U.S. fisheries with most of the shrimp caught in the Gulf of Mexico. Dockside value of the 209.93 million pounds of shrimp landed in the Gulf of Mexico in 1982 was \$425.75 million. In 1983, the poundage declined to 198.46 million with a value of \$416.91 million.

In recent years, imported shrimp volume has exceeded the domestic harvest and the imbalance is increasing. In 1983, the U.S. imported about 80 percent of all shrimp consumed domestically. The demand for shrimp is expected to increase at a time when harvests are at or near maximum sustainable levels.

Biologists conclude that there is no practical potential for increasing the harvest of shrimp from natural waters in the United States. Possibilities exist for farming saltwater and freshwater shrimp in the U.S., yet the economic feasibility remains to be demonstrated.

Farms in Central and South America are currently producing large quantities of shrimp, much of which finds its way into the U.S. market. Estimates are that Ecuador will export nearly 25 million pounds of shrimp into the U. S. in 1984.

Economic conditions in the U.S. shrimp fishery have led to increased harvesting costs while the total harvest has remained steady. This situation has resulted in rising costs per pound of domestic shrimp harvested.

An important consideration for processors is to lower costs of processing so as to better compete with imported shrimp. A dollar saved in processing cost is a dollar earned on the bottom line. The difficulty that many processors face is insufficient knowledge of their processing costs.

Many managers expressed a desire for more detailed analyses of processing cost functions and the capability to quickly determine the cost of each function and its impact on product cost. They also expressed an interest in personal computers and software to calculate the yield and final cost of various products.

VALUE OF PROCESSED SHRIMP PRODUCTS

Estimated processor value of shrimp products, excluding canned, was \$1,050 million in 1982 for about 260 million pounds of product, Table 1. This was up from the \$973 million and 259 million pounds in 1981. Total pounds remained virtually unchanged indicating that the dollar increase was primarily attributed to higher prices. Canned shrimp amounted to 1.176 million cases in 1982 with a value of \$45 million. These totals were down significantly from 1.828 million cases in 1981 with a value of \$59 million. Rock shrimp volume and value expanded significantly from 1976 to 1982. In 1976, landings of rock shrimp were 160,000 pounds valued at \$174,000. By 1982, the volume had expanded to 2.122 million pounds valued at \$5.6 million.

The Gulf of Mexico shrimp fishery is the largest in the country. In 1982, 191 million pounds of shrimp products were valued at nearly \$795 million, Table 2. The pounds of product declined by less than 5,000 from the previous year while the dollar value increased by nearly \$100,000, thus denoting a higher price per pound.

PROCESSING PLANTS AND EMPLOYMENT

There was an increase in seafood processing plants in the Gulf from 1976 through 1981, with a slight decline in 1982, Table 3. Total employment in the plants has remained relatively stable, with seasonal employment slightly greater than year-round employment at 15,314 in 1982 as compared to 11,221 in 1981.

Table 1. Shrimp: Quantity and Value of Processed Products 1976 - 1982

Item	Units	Thousands										1975			
		1982	1981	1980	1979	1978	1977	Quantity Dollars	Quantity Dollars						
Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars		
Raw Headless	Pounds	82,829	396,210	97,887	372,051	78,218	300,641	90,178	382,652	110,827	358,734	111,780	313,440	87,666	261,753
Cooked:															
Whole	do	41	80	1/	1/	1/	1/	117	905	1/	1/	1/	1/	1/	1/
Cocktails	do	2,971	6,938	2,430	6,111	2,813	5,840	2,973	5,838	1/	1/	1/	1/	1/	1/
Peeled, including deveined															
Raw	do	54,615	222,686	36,951	122,633	33,812	112,442	46,140	177,408	39,184	93,438	35,602	84,610	33,259	83,092
Cooked	do	21,807	77,602	33,601	122,488	23,149	85,218	23,871	73,501	41,303	116,647	23,277	51,779	18,876	41,744
Breaded, raw	do	77,839	271,537	70,261	228,548	67,226	203,400	80,944	217,870	90,175	205,695	91,907	206,345	95,923	202,912
Cooked:															
Breaded	do	15,158	61,526	13,950	51,204	14,368	46,582	16,039	54,077	18,392	49,149	5,041	9,170	2/	2/
Batter Coated	do	1,394	4,541	966	2,274	1,588	4,301	2,010	5,513	2,321	3,623	570	936	2/	2/
Breaded Raw and Cooked															
Patties and Burgers	do	288	625	340	680	325	568	1,678	2,698	1,462	1,964	2,618	3,083	2,525	3,012
Stuffed	do	2,503	8,299	2,215	7,063	1,443	6,342	1,556	3,855	1,484	2,981	1,456	2,766	1,517	2,938
Burgers, Croquettes, in baskets and salad mixes	do	314	361	1/	1/	748	1,077	823	2,819	787	1,797	997	1,914	938	1,233
Total		259,759	1,050,405	258,601	913,052	223,690	1,184,411	266,329	927,136	305,935	475,652	273,248	674,043	240,700	596,744
Canned:															
Natural Standard Cases		1,176	45,008	1,828	58,922	2,354	70,504	1,420	40,089	2,490	48,794	3,633	71,336	2,566	48,815
Dips, Pastes, Pickled, Soups and in Sauces	Pounds	21	859	22	944	23	939	25	940	31	1,305	46	1,942	34	1,382
Sun Dried	do	289	2,148	601	4,523	433	3,129	275	1,829	510	2,042	524	2,073	459	1,748
Total (excluding Canned)		260,069	1,053,412	2,451	64,389	2,810	74,572	1,720	42,858	3,031	52,141	4,203	75,351	3,459	51,945
Rock, Fresh and Frozen:															
Raw Headless	do	2,122	5,594	1,145	2,087	730	1,240	277	423	258	338	871	1,090	160	174

1/ Less than 500 tons
2/ Included in Breaded, raw

Source: Processed Fishery Products, Annual Summary, 1982, Current Fisheries Statistics No. 8303, USDC.

Table 2. Quantity and Value of Processed Shrimp from the Gulf Fishery, 1976 - 1982

Item	Units	1982					1981					1980					1979					1978					1977					1976				
		Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars	Quantity	Dollars							
-----Thousands-----																																				
Raw Headless	Pounds	80,803	387,077	95,446	364,488	76,567	294,326	88,809	376,827	109,848	355,521	109,984 ⁸	308,635	85,459	255,877																					
Peeled (including deveined):																																				
Raw	do	45,808	177,566	33,606	106,945	29,850	99,339	42,107	156,833	35,839	83,314	25,967	62,683	25,342	67,685																					
Cooked	do	3,489 ¹	17,289	8,096 ¹	35,302	2,084 ¹	8,293	2,857 ¹	10,091	2,378 ¹	7,333	1,213 ¹	4,162	930 ³	3,549																					
Breaded:																																				
Raw	do	57,609 ¹	198,041	55,581	179,880	53,068	156,029	62,775 ⁷	159,783	63,667 ⁷	136,735	53,178 ⁷	118,016	45,929 ¹	92,825																					
Cooked:																																				
Breaded and Batter Coated	do	1,949	6,284	841 ²	1,822	138 ⁹	229	559 ⁵	997	96 ⁸	132	78 ¹	110	10/ ¹⁰	10/ ¹⁰																					
Breaded Raw Stuffed	do	1,287	3,371	104 ⁹	189	1,022 ²	2,633	1,229 ²	2,779	1,366 ²	2,669	1,378 ²	2,642	2,507 ⁵	3,517																					
Sun Dried	do	289 ³	2,148	601 ³	4,523	433 ³	3,129	275 ³	1,829	510 ³	2,042	534 ³	2,073	459 ³	1,748																					
Subtotal		191,234	791,776	194,275	693,149	163,162	563,968	198,511	709,139	213,704	587,746	192,332	498,321	160,626	425,201																					
Canned Standard Cans		705 ⁴	28,512	1,071 ⁴	36,209	1,753 ⁴	58,725	890 ⁴	30,148	1,531 ⁴	33,563	2,130 ⁴	48,271	1,651 ⁴	32,606																					
Rock, Fresh and Frozen Raw Headless	Pounds	1,122	2,094	895 ⁶	1,664	484 ⁶	871	124 ⁶	194	178 ⁶	226	243 ⁶	280	10/ ¹⁰	10/ ¹⁰																					
Total		822,382		731,001		623,564		739,481		621,535		546,872		457,807																						

- 1/ Excludes Mississippi and Alabama
 2/ Excludes Mississippi
 3/ Louisiana only
 4/ Louisiana and Mississippi only
 5/ Excludes Mississippi and Texas
 6/ Florida only
 7/ Excludes Alabama
 8/ Excludes Texas
 9/ Alabama and Louisiana only
 10/ Not Available

Source: Processed Fishery Products, Annual Summary, 1982, Current Fisheries Statistics No. 8303, USDC.

Table 3. Processing Establishments and Employment, Gulf Fisheries, 1976 - 1982

	1982		1981		1980		1979		1978		1977		1976								
	Plants	Season Year	Plants	Season Year	Plants	Season Year	Plants	Season Year	Plants	Season Year	Plants	Season Year	Plants	Season Year							
	-----Employment-----																				
Florida	174	4,808	4,170	182	5,139	4,368	176	4,928	4,141	180	5,033	4,300	139	4,487	3,717	107	4,228	3,482	113	4,014	3,393
West Coast	62	2,323	1,496	56	1,777	1,261	51	1,738	1,179	54	1,780	1,281	50	1,869	1,284	50	2,298	1,488	43	1,839	1,297
Alabama	50	2,010	1,454	44	1,941	1,357	43	1,889	1,357	38	1,605	1,153	40	1,788	1,290	38	1,782	1,295	36	1,530	1,124
Mississippi	113	3,955	2,648	121	4,362	2,813	117	4,228	2,853	127	4,266	2,979	136	4,611	3,140	139	4,676	3,103	109	3,958	2,865
Louisiana	49	2,218	1,453	51	2,198	1,576	51	1,800	1,364	56	2,047	1,506	60	2,404	1,733	54	2,497	1,778	55	2,249	1,720
Texas	448	15,314	11,221	454	15,417	11,375	438	14,583	10,894	455	14,781	11,217	425	15,159	11,164	388	15,481	11,146	356	13,590	10,399
Total																					

Source: Processed Fishery Products, Annual Summary, 1982, Current Fisheries Statistics No. 8303, USDC.

PROCESSING COSTS AND VALUE ADDED

This analysis deals with plants processing primarily green headless frozen shrimp and multiproduct plants.

Green Headless

Data was obtained from 14 processors in the five Gulf states which processed primarily raw headless shrimp. A majority of the shrimp they produced was frozen in five-pound boxes. Most utilized brokers or wholesalers to market their products. Only a few performed their own marketing and sales functions. These processors reported a total sales volume of about 22 million pounds of processed shrimp in 1982, Table 4. This represents nearly 28 percent of the raw headless shrimp National Marine Fisheries Service (NMFS) reported for the Gulf states for that year, Table 1. Total reported sales were slightly less than \$88 million, or 23 percent of the total reported Gulf value. Processors paid an average of \$2.88 for raw materials, (about 72 percent of their total sales value) and average sales price for processed products was \$3.91.

Table 4. Sales, Costs, and Margins, 14 Green Headless Shrimp Processing Plants, Gulf of Mexico, 1982.*

	Lbs. and Cost	Percent of Sales
Sales vol. (lbs.)	22,115,000	
Sales (dol.)	87,892,000	100.00
Per lb. (dol.)	3.91	
Purchases (dol.)	63,470,000	72.14
Per lb. (dol.)	2.88	
Processing cost (dol.)	34,254,480	38.93
Value added (dol.)	24,512,000	27.86
Processing margin (dol.)	-9,742,480	-11.07

*Plants processing primarily green headless shrimp.

Processing costs accounted for about 39 percent of sales. This meant that those processors experienced a negative processing margin of about 11 percent or about \$9 million in 1982.

Total value added to green headless shrimp accounted for about 28 percent of sales or about \$1.03 per pound. A gross margin of about \$1.15 would have been necessary for those processors to break-even in 1982.

A detailed breakdown of costs is shown in Table 5. Operating costs accounted for about 59 percent of total costs with labor making up about

31 percent of the total. Packaging and marketing costs made up most of the balance of operating expenses. Overhead or fixed costs accounted for about 41 percent of the total with interest and depreciation being the most significant.

Table 5. Processing Cost Allocation for Green Headless Shrimp Processing Plants, Gulf of Mexico, 1982.

Cost Item	Percent of Total Cost
Operating Costs:	
Labor	30.82
Packaging	15.41
Utilities	7.72
Marketing	5.14
Total operating costs	59.08
Fixed Costs:	
Interest and depreciation	28.08
Administrative	2.57
Other	2.57
Total fixed costs	40.92
Total Cost	100.00

Multiproduct Processors

Multiproduct processors reported sales of about \$131 million in 1982, or nearly 32 percent of the total sales of processed products excluding green headless and canned products, Table 1. Average purchase price of raw materials was \$3.34 per pound, accounting for about 81 percent of the total value of products sold, Table 6. Selling prices averaged \$4.14 for finished products.

Operating costs exceeded fixed costs by a factor of three with operating costs accounting for about 16 percent of total sales value. Total value added was about 19 percent of total sales, or about \$.80 per pound of product sold.

Table 6. Percentage Cost Allocations, Multiproduct
Shrimp Processing Plants, Gulf of Mexico, 1982.

Item	Percent of Total Value
Raw materials	80.78
Operating Costs:	
Labor	6.46
Packaging	4.58
Utilities	0.54
Marketing	4.17
Total operating costs	15.75
Fixed Cost:	
Interest	.13
Depreciation	.25
Administration cost	2.77
Other	.32
Total fixed costs	3.47
Total Value	100.00
Value Added	19.22

Table 7 shows individual cost components as a proportion of total costs within the multiproduct plants.

Table 7. Percentage Cost Allocations, Shrimp Processing
Plants, Gulf of Mexico, 1982.

Cost Item	Percent of Total Cost
Operating costs	
Labor	33.63
Packaging	23.81
Utilities	2.79
Marketing	21.71
Total operating	81.94
Fixed costs:	
Interest	.68
Depreciation	1.32
Administration cost	14.39
Other	1.67
Total fixed costs	18.06
Total Cost	100.00

Processing Value Added

Value added through processing shrimp is defined as the difference between raw material cost and sales value of processed shrimp. Operating expenses, fixed costs and processor margins make up the total processing value added.

CONCLUSIONS AND RECOMMENDATIONS

A significant finding of this analysis is that plant managers generally have limited information on processing costs. Economic conditions in the domestic shrimp fishery and the growing volume of imports necessitate that they better understand and exercise greater control over processing costs. Cost control is vital if they are to remain financially viable.

Managers expressed a desire to have cost data available on a daily basis to determine the yield of raw material by size of shrimp and product form. This is essential if the managers are to price products properly and determine whether raw materials purchased are creating a profit for the firm. This was once done with pencil and paper; however, higher plant volume has rendered this virtually impossible. A solution is to utilize microcomputers. Software packages can be utilized at a relatively low cost to accomplish this as well as other plant functions.

It is recommended that managers establish economic information reporting systems which will provide a basis for more effective controls. University, governmental and other fishery support personnel should play a major role in assisting plant managers in fulfilling this need.

PRINCIPAL ECONOMIC FACTORS DETERMINING
U.S. SHRIMP PRICES AT ALTERNATIVE MARKET LEVELS

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University of Florida

INTRODUCTION

The production sector of the U.S. shrimp industry is characterized as presently being overcapitalized and fully exploited. In addition, fuel, vessel financing, insurance, and other costs have increased substantially in recent years. On the market side of the industry, imports have accounted for over 50 percent of U.S. consumption during the past two decades and more recently over 70 percent of the market. Current developments in foreign shrimp mariculture likely will lead to further increased levels of imports under present market conditions. The production sector of the industry has repeatedly requested restrictive measures on imports to improve their price situation and thereby relieve the cost-price squeeze they are presently experiencing. Others have suggested new market organizations and increased promotional programs to increase prices and/or to redistribute alleged excess profits which are suspected to exist at some levels in the market system. However, before the effectiveness of such policies can be assessed, a more complete understanding of the economic relationships determining price in the various segments and levels of the domestic market must be obtained.

Previously no research has been conducted to determine price relationships between adjacent market levels. In addition, research has not addressed the dynamic relationships which exist among adjacent market levels. Examining the direction of price formation, nature of price spreads, and speed of price adjustment will provide insight into the degree of competitiveness which exists in the market. Without an understanding of these relationships, differential market impacts of various price determinants and restrictive policy measures such as tariffs and quotas could not be analyzed at specified individual market levels and for other market dimensions, such as those defined by product size classes. The goal of the research reported in this paper is to provide information on which differential impacts can be estimated. The format of the present paper is to (1) review trends in prices, margins and market shares for 21-25 and 31-40 count (tails per pound) raw-headless shrimp, (2) determine direction of price flows and the nature of upward and downward price response between exvessel, wholesale, and retail market levels, and (3) determine factors affecting prices for the two size classes at the three market levels.

PRICE TRENDS

Shrimp prices at the exvessel, wholesale, and retail levels for the 31-40 (retail prices represent noninstitutional sales and only the

36-42 size class within the 31-40 class) and 21-25 size classes (tail count per pound) generally trended upward between 1968 and 1983 (Figures 1 and 2). However, during the 16 year period for which data were analyzed, prices, marketing margins, and shares varied widely (NMFS, 1972-82). Quarterly price movements at the exvessel (fishermen's) and wholesale market levels generally parallel each other for both 21-25 and 31-40 count shrimp. Retail prices also generally moved in the same direction as wholesale and exvessel prices, however, quarterly price changes appear to be less at retail. This was especially true from mid-1979 and through 1981. Wholesale and exvessel prices exhibited a general trend upward from 1968 through late 1982. However, preliminary data for 1983 through early 1985 indicate that prices for most size classes, and in particularly the middle sizes (21-25 through 31-40), have begun to trend downward (NMFS unpublished data).

The retail/wholesale and the wholesale/exvessel marketing margins are the difference between per pound prices at the respective adjacent market levels. The marketing margin between wholesale and exvessel price for 21-25 count raw-headless shrimp trended gradually upward at a rate of 1.6 cents per quarter for a total increase of 75 cents per pound and an average of 60 cents over the 47 quarter period analyzed. The fishermen's share of the wholesale dollar for 21-25 shrimp showed no statistically significant change, with a 47 quarter average of 85 percent. For the 31-40 count shrimp the marketing margin averaged 51 cents per pound, which was 9 cents per pound less than for the 21-25 count shrimp. The wholesale/exvessel margin for 31-40 count shrimp increased at a rate of 1.1 cents per quarter. The fishermen's share of wholesale dollar averaged 83 percent for 31-40 count shrimp, which was roughly equal to the share for 21-25 count shrimp. However, the fishermen's share for the 31-40 count shrimp increased at a statistically significant rate of .09 percent per quarter.

Marketing margins between retail and wholesale market levels behaved differently than the wholesale/exvessel margins during the 1972-83 period. Overall, the retail/wholesale margin for 21-25 count shrimp averaged \$1.62 per pound and increased an average of 5.2 cents per pound per quarter. This increase, however, appears to have occurred in three distinct time periods. During the 1972 through the mid-1979 period the margin increased slowly, but varied widely from quarter to quarter. From mid-1979 through early 1980 the retail/wholesale margin for the 21-25 count shrimp increased at an extremely rapid rate but has declined since early 1980 to relatively stable levels of \$2.25 to \$2.50 per pound. Wholesaler's share of the retail dollar for 21-25 count shrimp averaged 72 percent without any significant quarterly trend.

The retail/wholesale margins for 31-40 count shrimp generally showed the same trends as shown for 21-25 count shrimp. The margin averaged \$1.32 per pound and increased at a rate of 5.2 cents per quarter (same quarterly increase as for the 21-25 count shrimp). The wholesaler's share of the retail dollar was 72 percent, which also was the share for 21-25 count shrimp. However, the share declined at a statistically

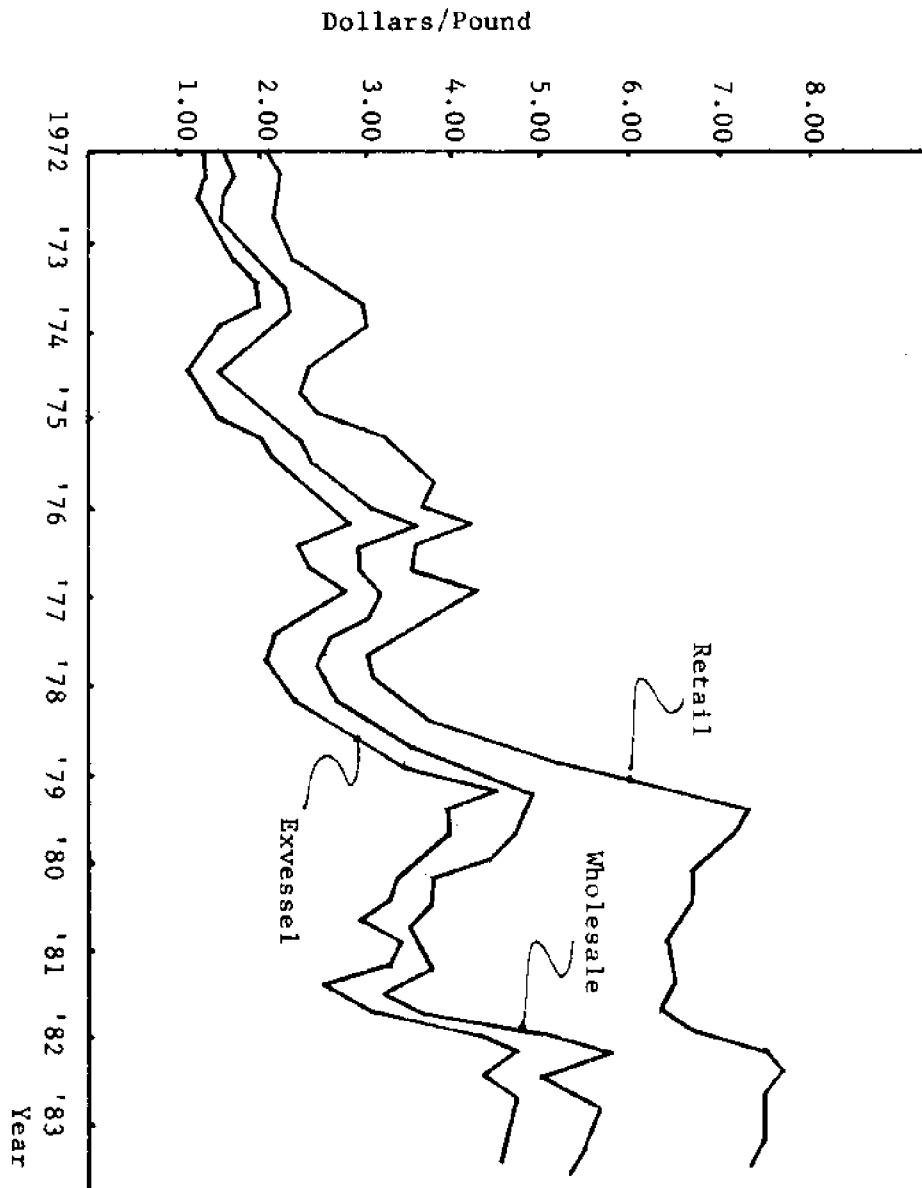


Figure 1. Trends In Quarterly Prices For 31-40 Count Raw-Headless Shrimp For Retail, Wholesale, And Exvessel Market Levels.

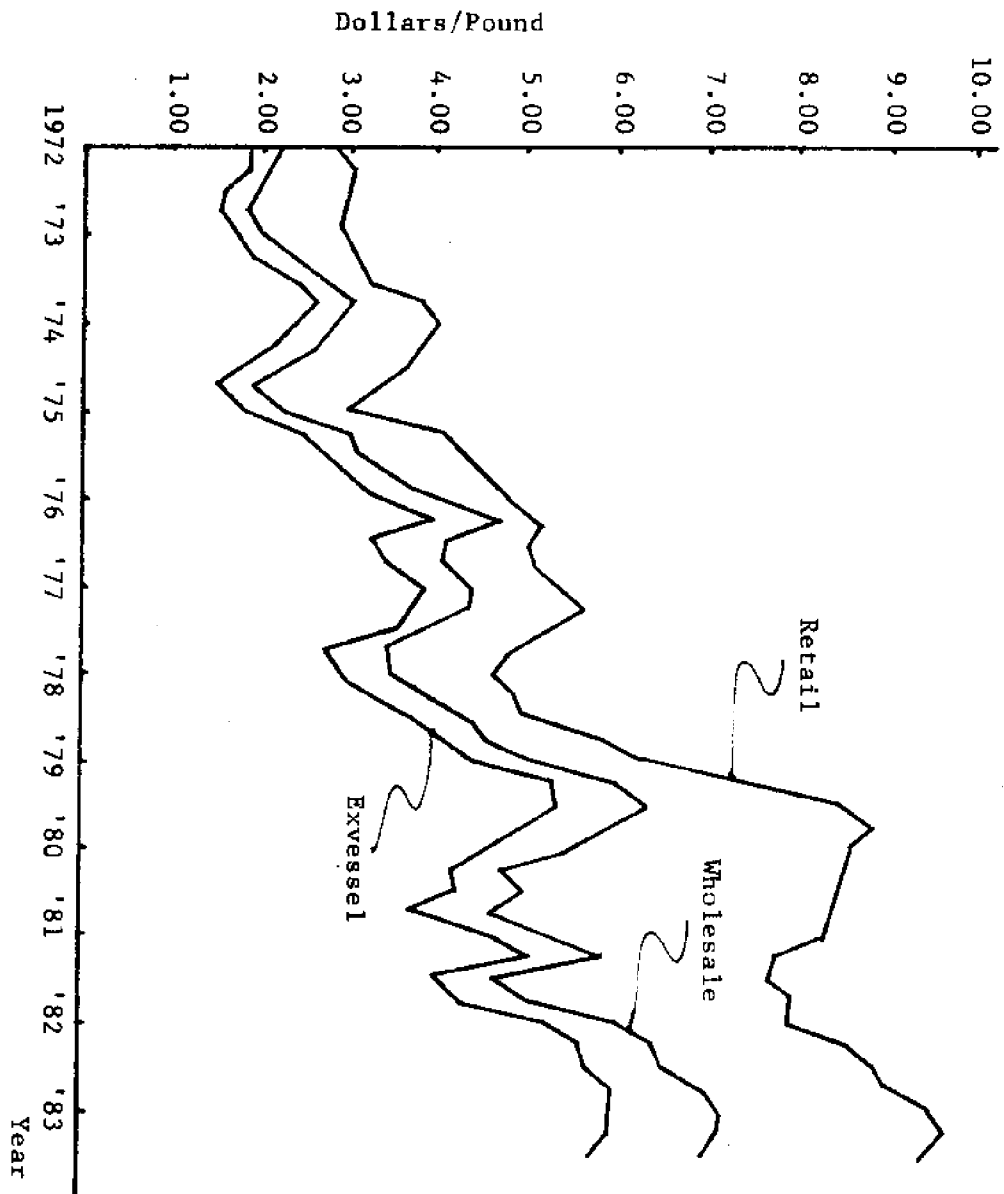


Figure 2. Trends In Quarterly Prices For 21-25 Count Raw-Headless Shrimp For Retail, Wholesale, And Exvessel Market Levels.

significant rate of .22 percent per quarter for the 31-40 count shrimp.

PRICE FLOWS: DIRECTION AND ASYMMETRY

Influence of one market level over another was examined with respect to causal direction and asymmetry (relative magnitude) of price response between adjacent market levels. Market prices are "marked up" or "marked down" when one market level leads (causes) an adjacent market level in final price formation, i.e. one price is determined after the other. When prices at adjacent market levels are determined interdependently then prices are simultaneously determined, i.e. both prices are determined during the same time period. Asymmetry of price response indicates a price will increase at a different rate than it will decrease. Asymmetry in price movements may slow equilibrium adjustments to market changes whether they be naturally or artificially induced. Asymmetric shifts in prices at the retail and wholesale market levels may occur, for example, if retailers are unwilling to relinquish gains in prices, even as wholesale prices stabilize or fall. In addition, if one market level has acquired an advantage through increased market power, price increases at the higher market level may not be passed down to lower market levels with the speed and degree that price decreases are. If this were the case, one market level may be able to control the price spread through influencing price at an adjacent market level. Statistical procedures suggested by Granger (1969), Sims (1972), Haugh (1972) and Pierce (1977) were employed to examine the causal direction of price determination for both quarterly and monthly price changes for 21-25 and 31-40 count raw-headless shrimp between exvessel, wholesale, and retail market levels. Tests of asymmetry as outlined by Young (1980) were performed on only monthly data.

On a quarterly basis, no one market level appeared to be dominant in determining prices. This conclusion suggests that over a quarter (three months) there is sufficient time for the wholesale and exvessel market levels to receive "feed back" from the retail market level such that events at one market level do not independently determine prices. Quarterly prices seem to adjust simultaneously with no apparent excessive market power at any market level for either 21-25 or 31-40 count shrimp.

The analysis of monthly data shows some difference in direction of monthly price flows compared to quarterly price flows. In the markets for 31-40 count shrimp there appears to be a "mark up" type of pricing. Monthly prices were shown to be dictated at the exvessel level which then determined wholesale and retail prices in a recursive (one after the other) manner, with marketing margins added at each level. In this short run market situation, exvessel market dominance is possibly explained by exogenous (predetermined) variations in landings. However, the quarterly analysis suggests that after a period of three months the retail market has sufficient time to respond to changes in the exvessel market, thereby playing a role in the determination of current market price by sending market signals down to the exvessel level.

The market situation in the 21-25 count shrimp markets is somewhat different from the 31-40 market on a short run monthly basis. Prices were concluded to be determined simultaneously between exvessel and wholesale market levels. This suggests more rapid adjustments to supply and demand conditions between these two market levels for 21-25 count shrimp than for 31-40 count shrimp. This is possibly due to the smaller size of the market and a greater expense involved in marketing the larger shrimp. However, on a monthly basis retail prices for the 21-25 count shrimp were concluded to be determined by wholesale prices. Thus, consumer market signals were again found to not be passed downward to the exvessel level on a short term month to month basis.

Asymmetric price movements were found to not characterize price changes for these two size classes of shrimp. This finding indicates that no one market level is able to effectively control the price spread between adjacent market levels.

PRICE DETERMINING FACTORS

A simultaneous equations model was estimated for each set of markets (21-25 and 31-40 count shrimp) to determine effects that real disposable income, total shrimp supply, price of substitute meat and poultry products, beginning shrimp stocks, imports, landings, and marketing costs have on shrimp prices. Prices were analyzed at the exvessel, wholesale, and retail market levels on a quarterly basis. The final form or long run equilibrium price effects resulting from changes in these causal factors are discussed in this section.

Consumer income was not found to be a statistically significant factor determining quarterly price changes (Table 1). This has generally been found for monthly and quarterly analyses while the effect is usually significant on an annual basis. Short run changes in real disposable income are probably too small to provide any explanatory power.

The consumer price index for meat and poultry products was entered into the equation system at the retail market level. The positive coefficients for 21-25 count shrimp indicate meat and poultry serve as substitutes for 21-25 count shrimp. Negative effects estimated for 31-40 count shrimp were concluded to be insignificant.

Total supply of fresh and frozen raw-headless shrimp also enters the system of equations at the retail market level. As expected, this variable had a negative impact on prices at each market level and, with the exception of 31-40 count retail prices, the price effects are greater at each higher market level. In fact, the absolute size of each effect is generally larger at higher market levels for all predetermined variables analyzed. The effects are more comparable, however, at wholesale and exvessel levels than between the wholesale and retail market levels.

Beginning stocks and imports were included in the structural equations at the wholesale market level and landings were entered at the exvessel levels. Beginning stocks had negative price impacts on

Table 1. Price Effects^a for Specified Predetermined Variables
at Exvessel(E), Wholesale(W), and Retail(R) Market Levels for
21-25 and 31-40 Count Raw-Headless Shrimp

Predetermined variables	21-25 count shrimp			31-40 count shrimp		
	R	W	E	R	W	E
Cents per pound change given a one -----unit change in predetermined variable-----						
Income ^b	- .28	- .09	- .08	- .39	- .69	- .63
Total supply ^c	- 2.74	- .92	- .79	- .38	- .67	- .60
CPIM ^d	1.52	.53	.44	- 1.51	- 2.70	- 2.45
Stocks ^e	- 2.39	- 1.45	- 1.25	-17.70	-11.80	-10.69
Imports: ^f						
Own	- 5.42	- 3.33	- 2.86	-58.03	-38.66	-35.03
Other	1.73	1.06	1.41	2.11	1.40	1.27
Landings: ^g						
Own	-32.47	-19.87	-19.00	-48.29	-32.19	-29.42
Other	- 1.89	- 1.16	- 1.11	- 1.78	- 1.19	- 1.08
Cost ^h	2.73	1.67	1.41	.86	.57	.48

- a. Price effects are from quarterly final form estimates
- b. Real (1972) disposable income in billion dollar units.
- c. Estimated as total disappearance from wholesale market of all sizes of raw-headless shrimp in million pound units.
- d. Deseasonalized consumer price index for red meat and poultry products (1972=100).
- e. Beginning inventories of raw-headless fresh and frozen shrimp in million pound units.
- f. "Own" imports are 21-25 or 31-40 count imports. "Other" imports refer to all other size classes of raw-headless shrimp imports in million pound units.
- g. "Own" landings are 21-25 or 31-40 count shrimp. "Other" landings are all other size classes of Gulf and South Atlantic shrimp landings in million pound units.
- h. Total food marketing cost index (1967=100).

both sizes of shrimp at all market levels. Own-size imports (21-25 or 31-40 count), own-size landings, and other landings also have negative effects on prices at all market levels for both size classes. The relatively large impacts for 31-40 count shrimp compared to those estimated for 21-25 count shrimp are particularly important in that the 31-40 size class represents the expected predominant size of shrimp to be imported from shrimp mariculture projects around the world. In general, the 31-40 size class is more price responsive to quantity changes than are the 21-25 count shrimp. Imports of shrimp other than 21-25 or 31-40 count shrimp were found to have an unexpected positive effect on prices for each size class. Theoretically, this positive effect was concluded to be statistically insignificant. This estimate reflects overall strong shifts in both import supply and demand over time. To separate these effects, simultaneous estimation of demand and supply functions would be necessary. However, sufficient data to perform the analysis are not available by individual size classes.

Marketing costs of intermediate goods and services for general food products resulted in positive price effects at all market levels. The positive effects were expected at the retail and wholesale market levels but not at the exvessel level. Added marketing cost can be expected to increase prices in upper market levels due to increased marketing margins. However, at the exvessel market level the derived demand is expected to be reduced which should result in lower exvessel price, *ceteris paribus*. The relatively larger effects for 21-25 count shrimp might be explained by higher interest costs for a more expensive product which spends more time as frozen inventory.

Price flexibilities (as percentage change in price given a percentage change in quantity) were also calculated. These estimates indicated the percentage price effects were relatively larger at higher market levels for the 21-25 count shrimp, but higher at lower market levels for the 31-40 count shrimp. In general, flexibilities at each market level were larger for the 31-40 count shrimp than for the 21-25 count.

PRICE INTERRELATIONSHIPS

Many of the causal factors affecting prices reviewed in the previous section do not directly affect price at each market level. They indirectly effect prices at a given market level through their direct effects on prices at adjacent market levels. For example, landings do not affect retail prices directly but they do impact retail prices through their impacts on exvessel and wholesale prices. Causal factors discussed above were included in the appropriate price model by virtue of economic logic and market information. Price interrelationships within and between market levels through time are further based on (1) structural relations suggested by tests of the direction of price determination and (2) statistical reasons such as corrections for serial correlation in model errors. Coefficient estimates which describe these price interrelationships are presented in Table 2.

Table 2. Estimated Relationships Among Retail, Wholesale, and Exvessel Prices for 21-25 and 31-40 Count Raw-Headless Shrimp.

Size class and market prices	Current prices			Prices lagged one quarter	
	<u>Retail</u>	<u>Wholesale</u>	<u>Exvessel</u>	<u>Retail</u>	<u>Wholesale</u>
-----Cents per one cent change -----					
<u>31 - 40</u>					
Retail		.556* (.108) ^a		.629* (.060)	
Wholesale	-.051 (.137)		1.110* (.093)	.041 (.093)	
Exvessel		.906* (.033)			
<u>21 - 25</u>					
Retail		.477* (.092)		.708* (.056)	
Wholesale	.356** (.195)		.798* (.131)	-.300** (.162)	.146* (.052)
Exvessel		.861* (.027)			

* Significant at the .05 level.

** Significant at the .10 level.

^a The values in parentheses are the standard errors of the estimates.

Retail prices for 31-40 count shrimp are significantly related to retail prices lagged one period and to wholesale prices in the current period. The estimates indicate a one cent increase in retail prices in the previous period will have a further impact of .63 cents in the current period. That is, those factors affecting retail prices in the previous period have further impacts in the current period. With respect to wholesale prices, a one cent increase in wholesale price increases retail prices by a little over one-half cent in the same period. Wholesale prices are in turn, significantly related to current

exvessel prices. Notice the nearly one-to-one relationship between exvessel and wholesale prices for 31-40 count shrimp. Exvessel prices are directly related to wholesale prices in the current period; a one cent change at wholesale results in a .91 cent change in exvessel prices. These strong relationships between wholesale and exvessel prices illustrate the close parallel in price trends for these two market levels.

Price relationships in the 21-25 count shrimp markets are similar to those estimated for the 31-40 count markets. Retail prices are significantly related to lagged retail and current wholesale prices. Exvessel prices are closely related to wholesale prices. The major price relationship difference between the 21-25 and 31-40 count shrimp markets occurs at the wholesale market level. In the 21-25 count shrimp market wholesale prices are significantly related to current retail prices, lagged wholesale prices, and lagged retail prices, in addition to the current exvessel price which the 31-40 wholesale price was also significantly related to.

SUMMARY AND CONCLUSIONS

One of the primary purposes in conducting the research reported in this paper was to evaluate the differential impacts imports and policy measures will have on various segments of the shrimp industry. Different market levels as well as different size count shrimp markets were analyzed. In the process of determining partial or independent effects of causal variables of direct concern, other basic information such as that pertaining to income, marketing cost, prices of competing meat products, etc. was developed. Although this information is vital to predicting unbiased consequences of the specific questions addressed, it also is necessary for a complete understanding of the economic relationships which exist within the U.S. shrimp market system.

The review of price and margin trends and estimated price relationships suggests all market levels will be impacted by changes in imports and/or policy measures. Impacts are nearly equal at the wholesale and exvessel levels with considerably higher impacts at the retail levels. Impacts at the retail and wholesale market levels will likely take longer to be fully realized.

No one market level appears to have sufficient market power to acquire an unequal share of the costs and benefits of increased or reduced trade. On a month-to-month basis it may appear that one market level will lead another in determining prices. However, this probably is due to factors other than market power, such as wide month-to-month variations in landings, marketing response time, and time required for market information to fully permeate the system. The latter criteria is suggested by the recursive nature of monthly price changes compared to the simultaneous nature of quarterly price movements. Although prices are simultaneously determined on a quarterly basis, price increases from restrictive trade policies can be passed on to higher market levels with proportionally larger price increases. In addition, the symmetric nature of price changes found in the analysis suggests

price reductions resulting from increased imports will be substantially larger at higher market levels. Also, given the weaker linkage between retail and wholesale prices than is found between wholesale and exvessel prices, policy measures administered at the retail level (market promotional programs) may have less of an impact on the total system than will policy measures administered at the lower market levels, such as implementing cooperatives or market orders.

Although the direction of price impacts is generally the same for the two size classes analyzed, there are some differences in terms of the magnitude of the effects. The 31-40 count shrimp market appears to be much more affected by changes in imports. This is particularly troublesome considering that this market is already subject to wider price responses than the 21-25 count shrimp market for comparable changes in other causal factors in the domestic market. Also the 31-40 count shrimp market will most likely be disproportionately impacted by new mariculture production which is expected to subject the domestic market to increased imports of shrimp of similar size.

The differing magnitude of price responses for the 31-40 and 21-25 count shrimp to changes in various causal factors is useful in assessing the market impacts of other policy measures. One such policy measure is the ban on shrimping in state and federal waters off the coast of Texas during a period in the summer season--otherwise known as the Texas Closure. The goal of the closure was to increase the quantity of large shrimp available for harvest in Texas and surrounding waters by protecting smaller juvenile shrimp early in the season. This is of particular interest to this study in that one of the two size classes most affected by the Texas Closure was the 31-40 size class (Klima, Baxter, and Patella, 1982). Given that the predominant size count of shrimp caught off the Texas and Louisiana coasts during the months immediately following the closure are of the 31-40 size class, the market for the 31-40 count shrimp may realize a larger impact due to policy measures, such as the Texas Closure, that alter the size distribution of shrimp harvested. This becomes increasingly important in light of the fact that other Gulf states are considering adopting their own closure policy. Public officials may want to reconsider the overall impact of this management tool on a total market basis, especially when considering this size class will most likely be affected by imports resulting from expanded shrimp mariculture production.

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MARKET STRUCTURE AND CHANNELS FOR FLORIDA
PROCESSED AND MARKETING OYSTERS

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INTRODUCTION

Florida production of oysters increased from approximately 3.5 million pounds of shucked meat during the early 1960s to an average in excess of 6.0 million pounds during the 1980s (Figure 1). This over all upward trend however, occurred with wide variations over three to five year periods. During the same period total U.S. production declined from approximately 60.0 million pounds to 50.0 million pounds annually. Florida production averaged 14 percent of total U.S. production during 1980-81. Oyster production within the state is concentrated in North Florida in Franklin County. Essentially all of the trends and growth in Florida oyster production comes from Franklin County landings, which accounted for 90 percent of total Florida oysters during the 1980s.

The purposes of the paper are to (1) describe the flow of Florida oyster landings into alternative product forms, (2) trace the marketing channels, with respect to source of raw products and distribution of products, by type of buyer and location, and (3) analyze revenues and costs incurred in marketing and processing of oysters by first dealer/processors. The data base consists of data acquired through personal interviews with Franklin County oyster dealers and processors. The sample covered 54 percent of local production during the 1983-84 season.

PRODUCT FORMS

Based on survey results only 32 percent of the volume handled originated from Florida landings (Figure 2) with the remaining 68 percent coming primarily from Louisiana and Texas landings. Shell stock products accounted for 57 percent of the total product handled. Out-of-state oysters represented the majority of shell stock product with Florida landed oysters accounting for 44 percent of the shell stock trade. Shell stock was further divided into washed and boxed 50 pound boxes (80 percent) and 60 pound bags (20 percent). These product forms were highly correlated with specific raw product source; 69 percent of washed and boxed oysters came from out-of-state landings while 82 percent of the bagged oysters were landed in Florida.

Shucked oysters accounted for 43 percent of total oysters handled. Out-of-state oysters made up 84 percent of the total shucked products.

Florida and Franklin County (Million Pounds).

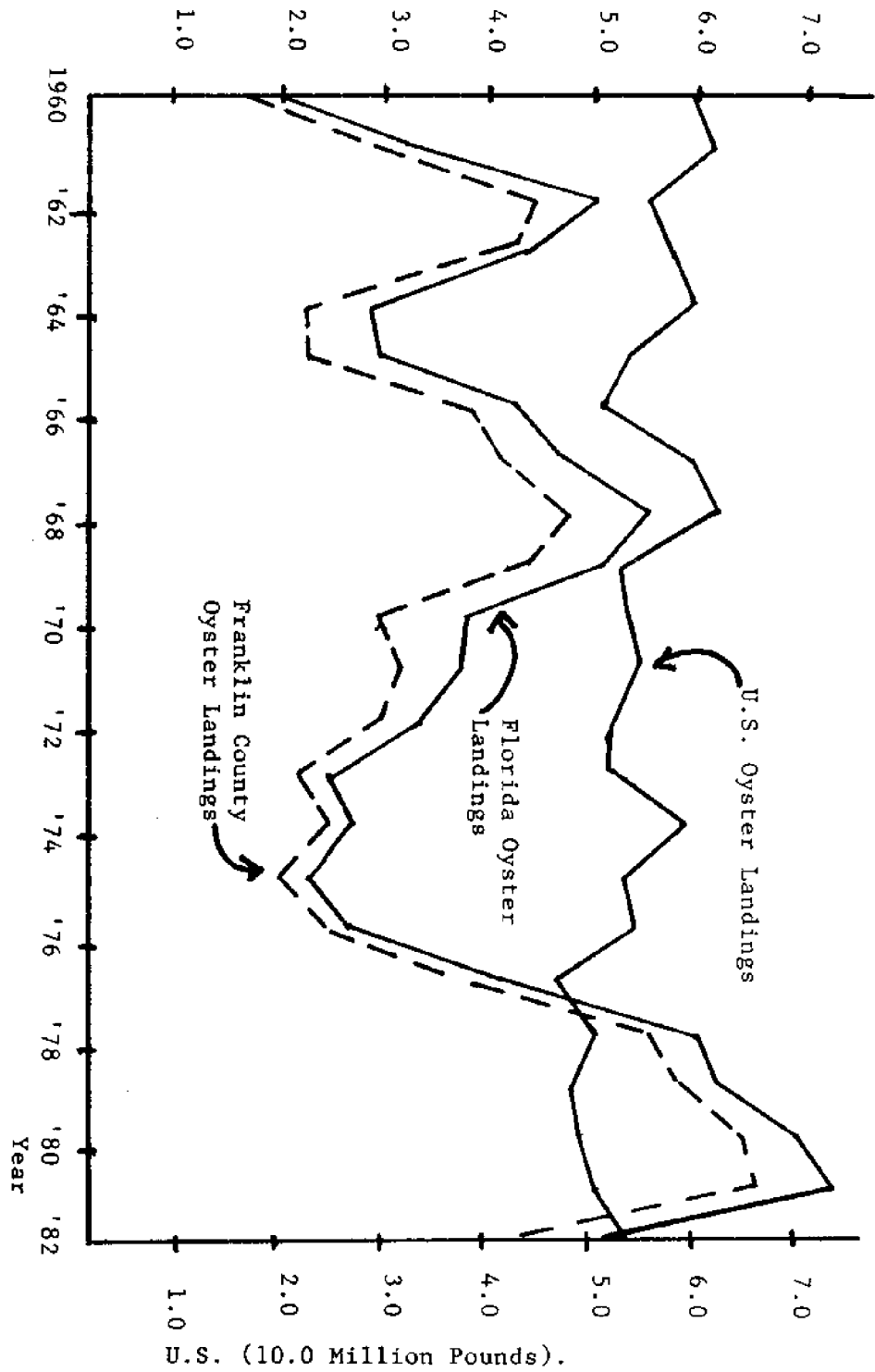


Figure 1. Franklin County, Florida and U.S. Oyster Landings (shucked meats).
 Source: NMFS, Florida Landings and Fisheries of the United States, U.S. Department of Commerce, Annual Issues

The reason for the large proportion of shucked out-of-state oysters is that these oysters are generally selects which bring higher prices and lower shucking costs per gallon than for the smaller Florida oysters.

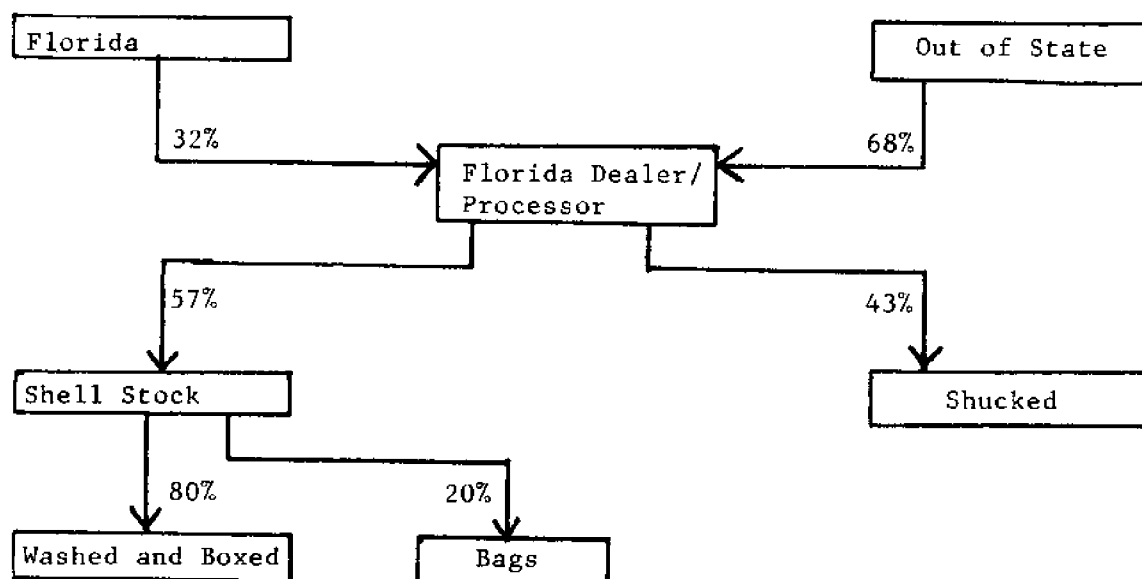


Figure 2. Oyster sources and product forms at Florida first dealer/processor market levels, 1983-84.

A closer look at market channels for oysters landed in Florida suggests several conclusions and raises some questions. Approximately 78 percent of the Florida oysters handled by firms interviewed were placed in the shell stock trade with the remaining 22 percent shucked. This distribution of products was reported by dealers to be due to local preferences for Florida oysters in the shell, lower costs per dozen in the half shell trade, and higher shucking cost for the smaller oysters landed in Florida. However, unpublished NMFS statistics suggested as much as 41 percent of Florida landed oysters were shucked in recent years. This discrepancy may be due to several reasons. The survey was based on larger first dealer/processors who operate year round. Smaller firms who often trade between local dealers on a seasonal basis may shuck a higher proportion of their total volume handled. Most of these firms were not operating during the closed season which was when the survey was taken. In addition, sales between local dealers were not counted in the survey to prevent double counting products

flowing into the various markets defined by product form and distribution by type of buyer and location. Examination of NMFS data did not further allow analysis of these questions because their data are on an annual basis rather than the seasonal basis used in the survey. In addition, out-of-state oysters used in the shell stock trade are not counted nor are sales between local dealers reported in the NMFS data.

PRODUCT DESTINATION: TYPE OF OUTLET

Approximately three quarters of the total volume handled by Florida first dealer/processors were sold to other wholesale distributors. Retail sales volume was split equally with 12 percent each to retail/seafood markets and restaurants (Figure 3). The distribution to alternative buyers or outlets by product form differed to some degree. Seventy-two percent of shell stock products were sold to wholesale distributors while 82 percent of the shucked product moved into this channel. The local preference for oysters in the shell is evidenced by 15 percent of this product moving directly to retail/seafood markets compared with 8 percent of the shucked product. Essentially no breeding takes place in the primary production area of Florida. The limited amount that is breaded in Florida is mainly in the Tampa and Miami areas which obtain much of their raw supply through wholesale distributors. The smaller, but nearly equal, percentage of product moving into restaurants reflects a greater variety of oyster dinners on the menus.

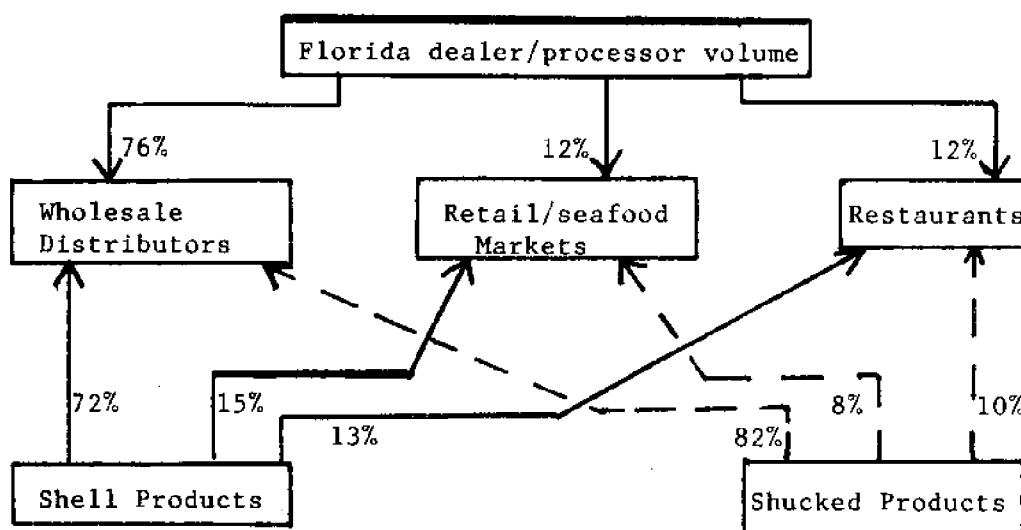


Figure 3. Product distribution of total volume and by product form; Florida first dealer/processors, 1983-84.

PRODUCT DESTINATION: LOCATION OF BUYERS

The large majority of first dealer/processor total sales volume goes to in-state locations; 63 percent were sold in state compared to 37 percent sold out of state during 1983-84 (Figure 4). The product mix differs by location of buyers. Florida first dealer/processors sold 61 percent of their shell stock to in-state buyers and 67 percent of their shucked products to in-state buyers. These shipments resulted in a product mix of 54 percent shell stock and 46 percent shucked product for in-state buyers. The shipments of 39 percent of shell products and 33 percent of shucked products to out-of-state buyers resulted in a product mix of 61 percent shell products and 39 percent shucked oysters for out-of-state buyers. The relatively large proportion of bulky shell stock going to out-of-state buyers is due to the fact that the majority of these sales are to Georgia buyers which in many cases are actually nearer to Franklin County than are many more distant Florida buyers.

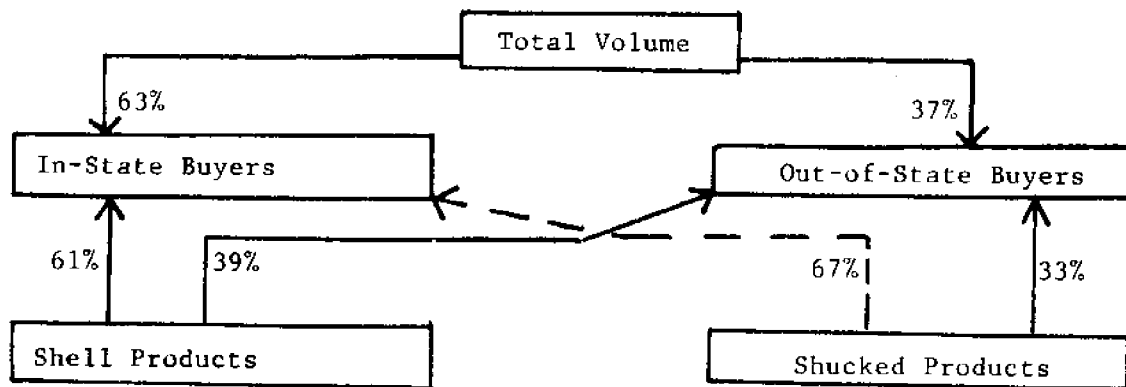


Figure 4. Locational distribution of oysters from Florida first dealer-processors, 1983-84.

REVENUES AND PRICES BY TYPE OF PRODUCT

Total revenue from oyster sales suggests even more the importance of out-of-state oysters than did comparison of volumes. Seventy-four percent of total sales resulted from the 68 percent of volume that originated from out-of-state oyster landings that were shipped to Florida first dealer/processors (Table 1). Nearly one-half of out-of-state oyster sales were from sales of shell stock with nearly all being washed and boxed. Sales of washed and boxed shell stock represented 54 percent of the sales produced from oysters landed in Florida. When shell stock

sold in 60 pound bags were included, however, a total of 78 percent of sales originating from Florida landings were generated through sales of unshucked oysters by first dealer/processors. Prices received for out-of-state shell stock were at premium compared to sales of equivalent volumes of oysters originating in Florida (Table 1).

Twenty-two percent of total sales from Florida oysters were from the shucked trade compared to 51 percent for sales based on out-of-state landings (Table 1). This difference is due to the greater volume of shucked out-of-state oysters and the premium price received. In total nearly three quarters of Florida first dealer/processor sales revenues were generated from oysters originating out-of-state.

Table 1. Florida Oyster First Dealer/Processors Revenues and Prices, 1983-84

ITEM	Oyster origin		
	Florida	Out of state	Total
Shell stock:			
Washed and boxed: (50 lbs.)			
Sales (dols.)	2,064,542	5,159,921	7,224,463
Percent	54	47	49
Price	\$9.95	\$11.43	
Bagged (60 lbs.):			
Sales (dols.)	928,337	274,155	1,202,492
Percent	24	2	8
Price	\$7.03	\$9.30	
Total shell stock:			
Sales (dols.)	2,992,879	5,434,076	8,426,955
Percent	78	49	57
Shucked (gallons):			
Sales (dols.)	849,642	5,557,276	6,406,918
Percent	22	51	43
Price per gal.	\$20.56	\$22.68	
Total oyster sales (dols.)	3,842,521	10,991,352	14,833,873
Percent of total	26	74	100

MARKETING AND PROCESSING GROSS MARGINS

The gross margin represents the difference in the FOB selling price and the delivered purchase price of an equivalent amount of product. For all three product forms (bagged, boxed and shucked) sale prices of oysters originating out of state exceeded those for products landed in Florida, while the purchase price of an equivalent amount of raw product was less for Florida landed oysters (Table 2). These price differences were due to differences in transportation costs, size or grade of oysters and seasonal demands and supplies (most out-of-state oysters were brought in during the off season in Florida). For all product forms the lower purchase price for Florida oysters more than offset the higher sales price for out-of-state oysters and thus resulted in a higher gross margin to dealers for handling and processing Florida landed oysters. The gross margin varied directly with the amount of processing. The gross margin was a low of \$1.40 per 60 pound bag of out-of-state oysters and a high of \$8.65 for a gallon of in-state oysters. One hundred pound out-of-state bags were converted to 60 pound bags.

Table 2. Marketing and Processing Gross Margins Incurred By Florida First Dealer/Processors, 1983-84.

Per Unit	Oyster origin	
	Florida	Out of State
Wash and boxed (50 lbs.):		
Sales price	\$9.95	\$11.43
Purchase price	<u>5.48</u>	<u>7.90</u>
Gross margin	\$4.47	\$ 3.53
Shell stock bags (60 lbs.):		
Sales price	\$7.03	\$ 9.30
Purchase price	<u>5.48</u>	<u>7.90</u>
Gross margin	\$1.55	\$ 1.40
Shucked (gal.):		
Sales price	\$20.56	\$22.68
Purchase price	<u>11.91</u>	<u>14.96</u>
Gross margin	\$ 8.65	\$ 7.42

NET OPERATING MARGINS

Net operating margins are the differences between gross margins and cost of processing and handling. Only direct costs of handling and processing were obtained and analyzed for washed and boxed oysters and shucked oysters. Marketing costs of bagged oysters could not be separated from overhead cost and costs of permanent full time employees.

Washed and boxed oysters have a direct cost of \$1.00 for the box and \$.50 per box for labor. Because of the higher gross margin for Florida landed oysters the net margin for returns to overhead and profits was greatest for Florida oysters (Table 3).

Table 3. Net Operating Margins for Oyster Products Processed by Florida First Dealer/Processors, 1983-84.

ITEM	Oyster Origin	
	Florida	Out of State
Washed and boxed:		
Gross margins	\$4.47	\$3.53
Direct costs:		
Box	1.00	1.00
Labor	.50	.50
Total direct costs	<u>\$1.50</u>	<u>\$1.50</u>
Net to overhead and profits	\$2.97	\$2.03
Shucked in gallons:		
Gross margin	\$8.65	\$7.42
Direct costs:		
Shucking labor	5.32	4.40
Container	.97	.97
FCA	.64	.53
Total direct costs	<u>\$6.93</u>	<u>\$5.90</u>
Net to overhead and profit	\$1.72	\$1.52

Labor is the principal cost in shucking oysters. Shucking labor for out-of-state oysters (including taxes) was less per gallon than for in-state oysters because of the difference in meat yields (out-of-state oysters yielding typically a larger meat. Total direct cost of shucked oysters was \$6.93 for Florida oysters and \$5.90 for out-of-state oysters during 1983-84. This cost difference offset the difference in gross margins to the extent that net margins for overhead

and profits were comparable at \$1.72 and \$1.52 per gallon for Florida and out-of-state oysters, respectively.

Net profits to management and ownership would require estimates of overhead costs. These costs were not computed because of a lack of data and/or confidentiality of individual data acquired. However, it appears that net profits may actually be higher for out-of-state oysters (especially for shucked products) because a substantial proportion of overhead is fixed and therefore would be incurred for the Florida landed operations regardless of the volume of out-of-state oysters handled and/or processed.

SUMMARY AND CONCLUSIONS

Even though Florida landings have been increasing while U.S. landings have been decreasing, Florida first dealer/processors were highly dependent on out-of-state oyster landings during 1983-84. Most out-of-state oysters were processed into washed and boxed oysters and shucked oysters while most Florida landed oysters entered the shell stock trade. Nearly three quarters of the oyster products were sold to other wholesale distributors which generated additional employment and dollar impacts. The 25 percent of sales made directly to retail outlets and restaurants was heavily weighted with shell stock products. In terms of location of buyers, the market channels were relatively short with two thirds of first dealer/processor sales made to other in-state buyers and most out-of-state sales made to neighboring states. Both selling and purchase prices of out-of-state oysters were higher than those for Florida landed oysters, however, gross and net margins to overhead and profits were higher for Florida landed oysters.

A few qualifications may alter the conclusions slightly. The results of this analysis are based on survey data for the 1983-84 season. Most of the data represent operations of full time, relatively large dealers and processors. The actual proportion of total volume represented by shucked product may be slightly higher than reported in the survey if the small part-time firms shuck a higher proportion of their total volume.

An additional qualifier may be appropriate with respect to the relative importance of out-of-state oysters. Florida oyster landings during 1983-84 were below those for the previous two seasons (however, they were above most other years). Market expansion during the peak production years may have encouraged a large demand for out-of-state oysters during the 1983-84 season and, thus, the dependency on out-of-state oysters may not be representative of longer time periods.

REFERENCES

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- NMFS, Florida Landings, U.S. Dept. of Commerce. Annual Issues.

Forecasting U.S. Shrimp Prices:
A Comparison of Three Different Models

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INTRODUCTION

The amount of shrimp consumed in the United States has risen steadily in the past few years, reaching a record in 1984 of 536 million pounds of fresh and frozen shrimp. Eighty percent of the shrimp eaten in America was consumed in restaurants (Seafood Business Report, 1984). Even though the U.S. landed 160 million pounds of shrimp in 1984, 343 million pounds were imported, a record quantity. The strong U.S. dollar certainly played a part in these quantities of shrimp entering America.

The size composition of imports has also changed in recent years. Since 1981, Ecuador has been successfully raising shrimp in ponds. Although no data are currently available on how much aquacultured shrimp enters the U.S., it has been estimated that 15 to 20 percent of all imports--about 75 million pounds--were aquacultured shrimp in 1984. Although this is a large quantity of shrimp, the impacts that these imports have on the U.S. shrimp market are concentrated in the 26- to 40-count size range since the shrimp are usually raised to these sizes. So aquaculture has changed the quantity ratios between sizes of shrimp that would occur if all shrimp were harvested from wild stocks.

Prices of shrimp have historically been volatile. The previously described changes in the marketing system will have a continuing impact on shrimp prices. This research was undertaken to increase the understanding of the nature of these fluctuations. This could be useful to the industry and those that manage the industry. Two different techniques for price forecasting will be discussed in this paper: (1) time series models and (2) econometric models. A description of each follows.

TIME SERIES MODELS

A time series model is one that replicates the systematic behavior of a variable based on the variable's past behavior (Pindyck and Rubinfeld, 1981). Simple time series models include extrapolation, such as a linear trend model, $y_t = A + bt$, in which "y" is the forecasted

series, "t" is the time period, and "A" and "b" are estimated coefficients; and moving average models, in which the last three months' value of the variable is averaged to give a forecast of the variable.

A simple time series model for shrimp prices can be found in Thompson and Roberts (1981). The model was developed by calculating monthly price indices for 26- to 30-count shrimp. These models do not account for the random nature of the variable. They are known as deterministic models.

It is possible to construct time series models that do account for the random nature of a variable. These include moving average models (MA), autoregressive models (AR), and a combination of the two, known as autoregressive integrated moving average models (ARIMA). The following discussion was condensed from Pindyck and Rubinfeld, 1981.

When estimating a time series model, the time series must be stationary. That is, the mean and variance of the time series are constant over the data base time period.¹ There are few data series that can be defined as stationary. It is possible to create a stationary time series from a homogeneous nonstationary time series by differencing it one or more time.²

In moving average models, MA(q), in which "q" is the order of the process, the time series Y_t is generated by a weighted average of the random disturbances going back "q" time periods.³ For the autoregressive model, AR(p), "p" is the order of the process. In this case, Y_t is generated by a weighted average of past observations going back "p" time periods, combined with a random disturbance in time "t."⁴

These models can be combined in an ARIMA (p,d,q) model, in which "d" is the number of times the time series was differenced to make it a

¹in which the mean is defined as $My = E(Y_t)$ and variance = $\sigma^2 = E[(Y_t - \mu)^2]$.

²That is $\Delta Y_t = Y_t - Y_{t-1}$. The new time series ΔY_t is used in the estimation process.

³ $Y_t = \mu + \varepsilon_t - Z_1 \varepsilon_{t-1} - Z_2 \varepsilon_{t-2} - \dots - Z_q \varepsilon_{t-q}$
in which μ = mean of series Y_t
 ε_t = error in time period t
 Z_i = the coefficients

⁴ $Y_t = Q_1 Y_{t-1} + Q_2 Y_{t-2} + \dots + Q_p Y_{t-p} + d + \varepsilon_t$

where: Y_t = the time series variable
 d = a constant relating to the time series
 ε_t = the error in time "t"
 Q_i = the coefficients

stationary series. (If differencing is not necessary, the model is referred to as an ARMA (p,q) model.) The various mathematical properties and the estimation techniques used for models of this type are detailed in various textbooks.⁵ There are few statistical tests and fewer rules that can be used when attempting to estimate a time series model. It is as much an art as it is a science.

Presentation of the Model

The estimation of the time series model was done using the "PROC ARIMA" procedure from the Statistical Analysis System (SAS) program (SAS ETS Users Guide, 1982). The time series data were the 31- to 35-count size, exvessel price of shrimp for the northern Gulf of Mexico. The data were compiled from Shrimp Statistics, published monthly by the National Marine Fisheries Service (NMFS) and covered the period from September, 1974, to October, 1984. The data were not stationary. After differencing one month, the time series appears stationary.

Two models were estimated from the differenced data, an ARIMA (1,1,1) and an ARIMA (1,1,2).⁶ Diagnostic testing showed little difference between the two models, so the ARIMA (1,1,1) was selected. Table 1 contains the results of the test for white noise.⁷ Since the

Table 1. Autocorrelation Check for White Noise

LAG	DEGREES OF CHI SQUARE FREEDOM			PROB	AUTOCORRELATIONS				
6	32.24	6	0.000	0.478	0.160	-0.047	-0.070	-0.013	-0.004
12	35.96	12	0.000	0.111	0.048	0.078	0.071	0.011	0.051
18	50.09	18	0.000	0.011	-0.061	-0.142	-0.155	-0.170	-0.151
24	72.27	24	0.000	0.153	-0.196	-0.157	-0.108	-0.096	-0.204
30	77.06	30	0.000	-0.134	-0.064	-0.027	-0.045	-0.024	-0.072
36	95.27	36	0.000	-0.068	-0.082	-0.012	0.077	0.205	0.215
42	105.89	42	0.000	0.096	0.085	0.059	0.051	0.097	0.161

⁵These include Pindyck and Rubinfeld, 1981, Bowerman and O'Connell, 1979, and O'Donovan, 1981.

⁶These were selected by examination of the autocorrelation and partial autocorrelation functions and graphs of the data. See previously cited texts for details.

⁷A white noise process is totally random. The best forecast of future values is the last available value in the time series. Modeling is irrelevant.

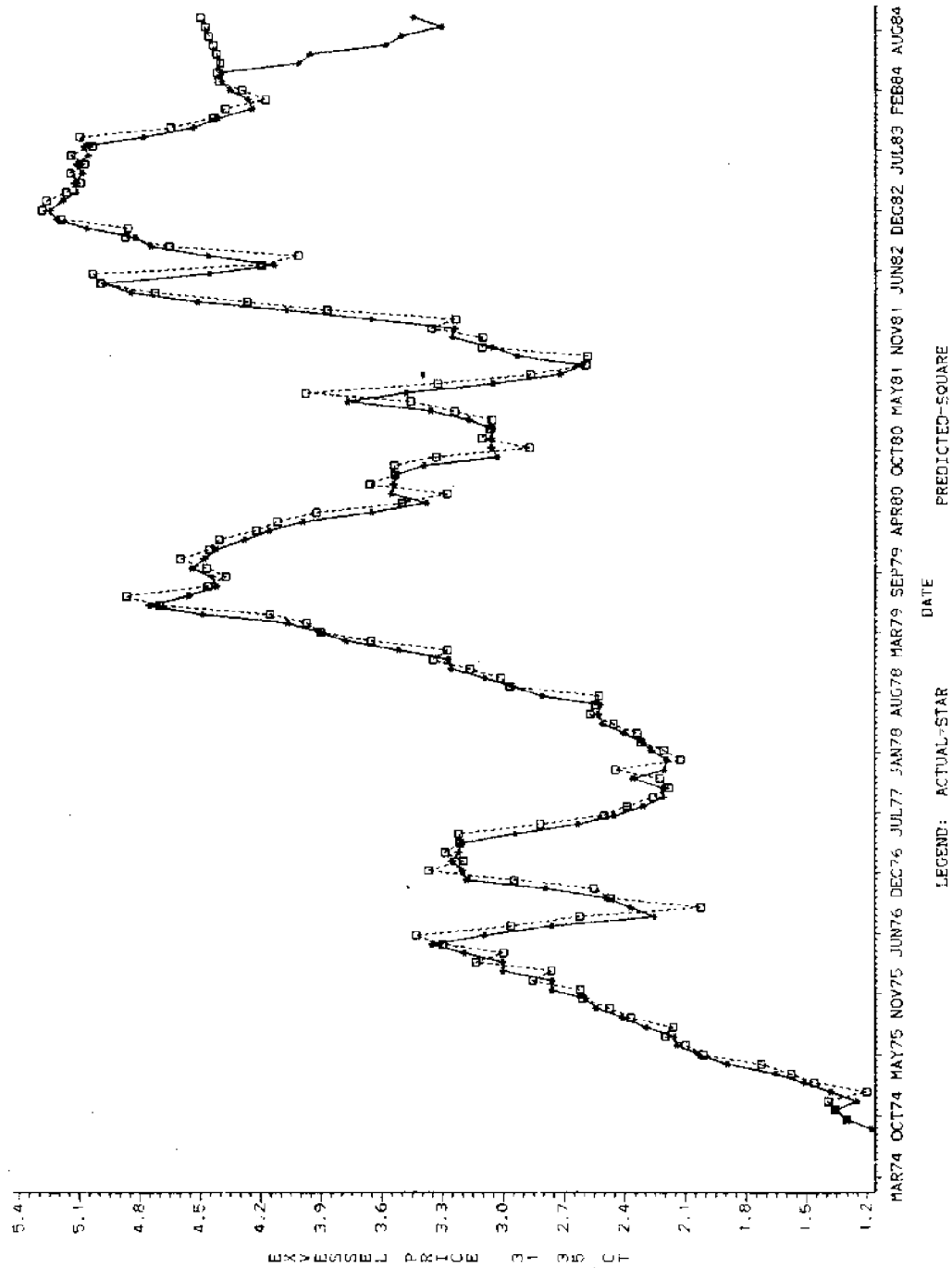


Figure 1. Actual and ARIMA (1,1,1) forecasted 31-35 count exvessel shrimp price.
(6/85 to 10/85 represents an ex post forecast.)

price data were not generated by a white noise process, the forecasting process continued. The parameter estimates were as follows:

Table 2. ARIMA Parameter Estimates

PARAMETER	ESTIMATE	STD. ERROR
MU	0.016	0.030
MA	-0.126	0.190
AR	0.385	0.176

The residuals from the model were examined. If they are highly correlated, the model has failed to explain a significant amount of variation in the time series. Table 3 shows that the residuals are not highly correlated.

Table 3. Autocorrelation Check of Residuals

LAG	DEGREES			PROB	AUTOCORRELATIONS				
	CHI	OF	SQUARE FREEDOM						
6	3.12	3		0.374	0.009	0.033	-0.101	-0.069	0.047 -0.079
12	8.84	9		0.452	0.158	-0.051	0.052	0.066	-0.061 0.073
18	11.92	15		0.685	0.023	-0.018	-0.091	-0.054	-0.085 -0.050
24	20.27	21		0.504	-0.033	-0.120	-0.062	-0.031	0.033 -0.185

Figure 1 contains the actual and forecasted prices for 31- to 35-count shrimp. The models, though it simulates the historical prices closely, does not simulate the turning points well. Normally, the turn is picked up one month late. Also, the six-month forecast (May to October, 1984) does not follow the actual prices well at all. Forecasts of prices for November, 1984, to April, 1985, are presented in Figure 2, along with the 95 percent confidence intervals.

ECONOMETRIC MODELS

Econometrics is the combination of statistics and economics that is used to build representations of economic activities. The simplest form of an econometric model can be represented as:

$$Y = a + by + \varepsilon$$

where: Y is the dependent variable that is being modeled,
X is the independent variable which is being used to explain Y,
a + b are the estimated coefficients, and ε is the error term.

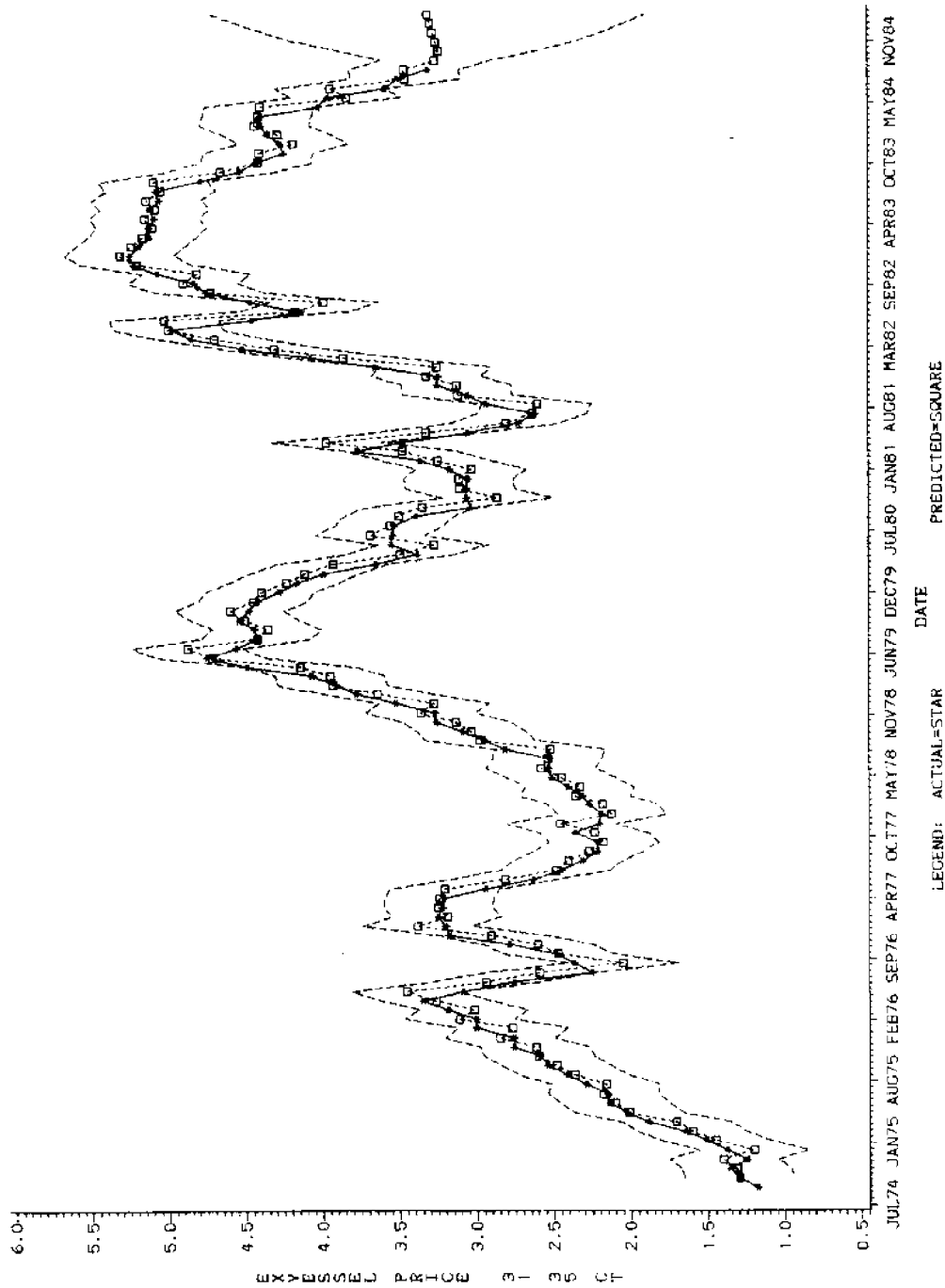


Figure 2. Actual and ARIMA (1,1,1) forecast of 31-35 count exvessel shrimp price, including 95 percent confidence intervals.

There are two major differences between the econometric model and the previously described time series models. The first is obvious; more than one variable is used in the estimation process. The independent variable is expressed as a function of the dependent variable. The second difference is the hypothesis that the changes in variable Y are caused by the changes in variable X. This is the manner in which the economic theory is tied to statistics. The equations are constructed in such a way that hypothesized economic relationships can be tested statistically.

Econometric models are not limited to the simple model above. It is possible to construct a model in which the dependent variable is a function of two or more independent variables. It is also possible to create a system of equations to model an economic phenomenon. A model such as this may be set up in the following manner.

$$P_t = b_0 + b_1 Q_t + b_2 Y_t + b_3 T$$

$$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 B_t + \alpha_3 C_t$$

where: P = the price of shrimp,
 Q = the quantity of shrimp on the market,
 Y = disposable income
 B = biological factors that effect shrimp harvest,
 C = cost involved in shrimp harvesting.
 T = personal tastes of consumers

All defined for time period t.

Thus, in the above model, the current price level for shrimp is dependent upon the current quantity of shrimp supplied, which would be dependent on the current price. These are jointly dependent variables.

The reasoning behind such jointly dependent variables is easily explained. It is possible to estimate a single equation model for shrimp price and to use it to make forecasts, but this is an incorrect procedure. The quantity of shrimp available fluctuates from month to month because of the changing levels of landings, imports, and cold storage holdings. The amount of shrimp consumed in the U.S. also varies from month to month. As is given by economic theory, the price of a commodity is set at the intersection of supply and demand. So the prices should not be represented by a single line, since each point represents an intersection of shrimp supply and shrimp demand.⁸ The shrimp model should take this into account; a simultaneous model is needed.

A seven-equation, simultaneous model of the shrimp industry was estimated using the econometric technique known as three-stage

⁸A good introductory econometrics text is Hu (1982). Readers with a stronger statistics/matrix algebra background may want to try Pindyck and Rubinfeld (1981), or Johnson (1963).

least-squares (3SLS). This technique was chosen because it estimates simultaneous equations and can be more efficient than other estimation methods when cross-equation correlation is present in the system.⁹ The following model was estimated using the Statistical Analysis System (SAS) computer package:

$$PW = f (ST_{t-1}, I, AC, P_t, P_{t-1}, Q2, Q3, Q4)$$

$$P = f (PW, PW_{t-1}, L, R, Q2, Q3, Q4)$$

$$I = f (PW_{t-2}, X_{t-2}, IMD, Q2, Q3, Q4)$$

$$L = f (PR_{t-2}, T_{t-2}, TR, Q2, Q3, Q4)$$

$$TR = f (P, F, L, Q2, Q3, Q4)$$

$$ST = f (ST_{t-1}, I, L, AC)$$

$$AC = f (PW, E, Q2, Q3, Q4)$$

Table 4 contains a brief description of each variable and indicates whether it is endogenous (jointly determined by the model) or exogenous (determined outside the model). In order to create a forecast, it is necessary to provide a forecast for each exogenous variable throughout the forecast period. Variables that are lagged are identified by t-, the period of the lag. The model was estimated using monthly data from September, 1974, through October, 1984.

DESCRIPTION OF THE EQUATIONS

Wholesale Price Equation

The wholesale price for 31- to 35-count shrimp was estimated as a function of cold storage lagged one month, imports, apparent consumption, and current and lagged exvessel price. The seasonal nature of shrimp price fluctuation was accounted for by the inclusion of dummy variables.¹⁰

⁹The mathematics behind 3SLS is beyond this paper and beyond many econometric texts. The reader is referred to Zellner and Theil, 1962.

¹⁰A dummy variable can be used when a hypothesized relationship has no quantifiable data. It is only equal to 1, which indicates that the relationship is occurring, or "0" when the relationship is not. Hence, for April, May, and June, Q2=1; but Q2=0 for all other times of the year. It would not be possible to estimate an equation if Q1, Q2, Q3, and Q4 were included in it, as this would cause perfect multicollinearity (Q1+Q2+Q3+Q4=1 for all variables). The parameters for Q2, Q3, and Q4 show the difference between those seasons and Q1, which is the base season.

Table 4. Descriptions of Variables

SYMBOL	DEFINITION	TYPE
PW	Wholesale price 31- to 35-count shrimp at New York (heads off, \$/lb)	endogenous
P	Exvessel price 31- to 35-count shrimp for northern Gulf (heads off, \$/lb)	endogenous
I	Imports of shrimp in thousands of pounds, heads-off weight, excluding canned shrimp	endogenous
L	Landings of warm-water shrimp, U.S., in thousands of lbs, heads-off weight	endogenous
TR	Gulf shrimping trips	endogenous
ST	Cold storage holdings of shrimp, heads off, thousands of pounds	endogenous
AC	Apparent consumption of fresh and frozen shrimp, thousands of heads-off pounds	endogenous
R	Prime interest rate on short-term loans to business	exogenous
X	Exchange rate between U.S. and Japan (yen/dollar per value)	exogenous
IMD	Dummy for 1983 through 1985	exogenous
PR	Average precipitation, southern Louisiana in inches	exogenous
T	Average temperature, southern Louisiana (°F)	exogenous
F	Average diesel fuel price (\$/gallon)	exogenous
Q2	Second quarter dummy	exogenous
Q3	Third quarter dummy	exogenous
Q4	Fourth quarter dummy	exogenous

Cold storage, imports, and consumption were hypothesized to affect wholesale price directly.

The effects of other variables that indirectly affect wholesale price are accounted for by the simultaneous nature of the model.¹¹ Current and lagged exvessel price was included, because it was hypothesized that wholesalers do not base purchasing decisions solely on current price, but also examine price trends. This is done by examining previous prices.

Exvessel Price Equation

The exvessel price equation includes current and lagged wholesale prices, Gulf and south Atlantic landings of shrimp, and the prime interest rate. Lagged price was included in the exvessel equation for the same reason as in the wholesale price equation. The prime interest rate was included in this equation since it was hypothesized that the prime interest rate would affect the cost of storing shrimp for future use, and the change in these costs would be passed down to the shrimper through changes in exvessel price (Thompson and Roberts 1981). Seasonal dummies were again included to explain changes in landings from one time of the year to another.

Imports Equation

The import equation was estimated as a function of wholesale price, the exchange rate between Japan and U.S., both lagged two months. The equation also included the seasonal dummies and an additional dummy variable for 1983, 1984, and 1985. The exchange rate was included in the equation because Japan and U.S. are the two largest markets for shrimp. As the exchange rate between the two countries fluctuates, the countries' currencies become relatively more valuable. Exporters of shrimp prefer to sell to the nation that has the more valuable currency. A lag of two months was chosen after lags from zero to six months were examined (Thompson and Roberts, 1981). The dummy variable for 1983, 1984, and 1985 was included to explain the increases in imports to the U.S. in recent years.

Landings Equation

The majority of Gulf shrimp harvested are estuary-dependent during the early stages of their life cycle (Management Plan). Adverse conditions during this time lower the shrimp harvested in the Gulf. Precipitation and temperature in southern Louisiana are used as variables in the equation. Another variable that was investigated was Mississippi River

¹¹For example, landings affect exvessel price, which in turn affects wholesale price.

water discharge, but the data were not available on a timely basis (Thompson and Roberts, 1981).

The number of Gulf shrimping trips was included as a measure of effort involved in the industry. A superior measure of shrimping effort would include number of shrimping trawls made, amount of trawl soak time, and total amount of horsepower involved in the industry in the month. This information was not available. The equation also included the dummy variables to explain the seasonal fluctuation in the fishery.

The landings equation also included the harvest from the south Atlantic area, for which there were no comparable data as was described above. There was a very high correlation between Gulf and south Atlantic landings ($R < .90$), so both were included in the equation. In this way, the model accounts for all U.S.-landed warm-water shrimp.

Trips Equation

Trips were expressed as a function of exvessel price, landings, diesel fuel prices, and the seasonal price dummies. Fuel costs constitute the majority of the variable costs in shrimping trips. Data on other costs, such as groceries, labor, and equipment, were not available.

Stocks Equation

Cold storage holding of shrimp (stock) was expressed as a function of lagged stocks, imports, landings, and apparent consumption. These variables constitute the majority of stock, it is not an identity as U.S. exports and re-exports are not included in the equations. Attempts to make this equation an identity decreased the model's ability to make predictions.

Apparent Consumption

The apparent consumption equation included wholesale price, spending in eating places, and the seasonal dummy variables as the independent variables. Spending in eating places was included in place of real disposable income since the later variable was highly correlated with wholesale price and caused estimation problems in the model. In addition, spending in eating places is seasonal, a factor that helps to explain seasonal variation in apparent consumption.

MODEL SELECTION

In order to demonstrate the methods used to select a model, two different models will be discussed. The first, which will be called Model I, has been described previously in the paper. Model II differs from Model I in that its seasonal dummy variables were four months long

(January, February, March, and April, etc.). Table 5 contains the Root Mean Square Error¹² (rms error) for the two models.

Table 5. Root Mean Square Errors

EQUATION	MODEL I	MODEL II
Wholesale Price	.297	.266
Exvessel Price	.232	.241
Imports	4011.7	4180.15
Landings	5740.15	3188.82
Trips	15333.8	11096.1
Stock	4114.37	3806.26
Apparent Consumption	5725.3	5403.13

The two numbers that were of the most importance to this study were the rms errors for the two prices in the model. Even though Model II had lower rms errors for five the the eight variables, there is another consideration that must be examined: the model's ability to predict turning points in the prices. The following graphs depict both model's ability to make forecasts of prices. Each graph is a six-month ex post forecast of exvessel price.¹³ As can be seen from the graphs, Model I picks up the turning point in the final month of forecast (Figure 3), while Model II turns prematurely (Figure 4).

This leads to the third criterion of testing for a forecasting model: the ex post rms forecasting error. This is the rms error

¹²rms error is defined as:

$$\frac{1}{T} \sum_{t=1}^T (Y_t^P - Y_t^A)^2$$

where:

Y_t^P = Predicted value in time t

Y_t^A = Actual value in time t

T = Number of time periods.

¹³An ex post forecast is made when the observations for both the exogenous and endogenous variables are known with certainty. An ex ante forecast is one made with forecasted exogenous variables.

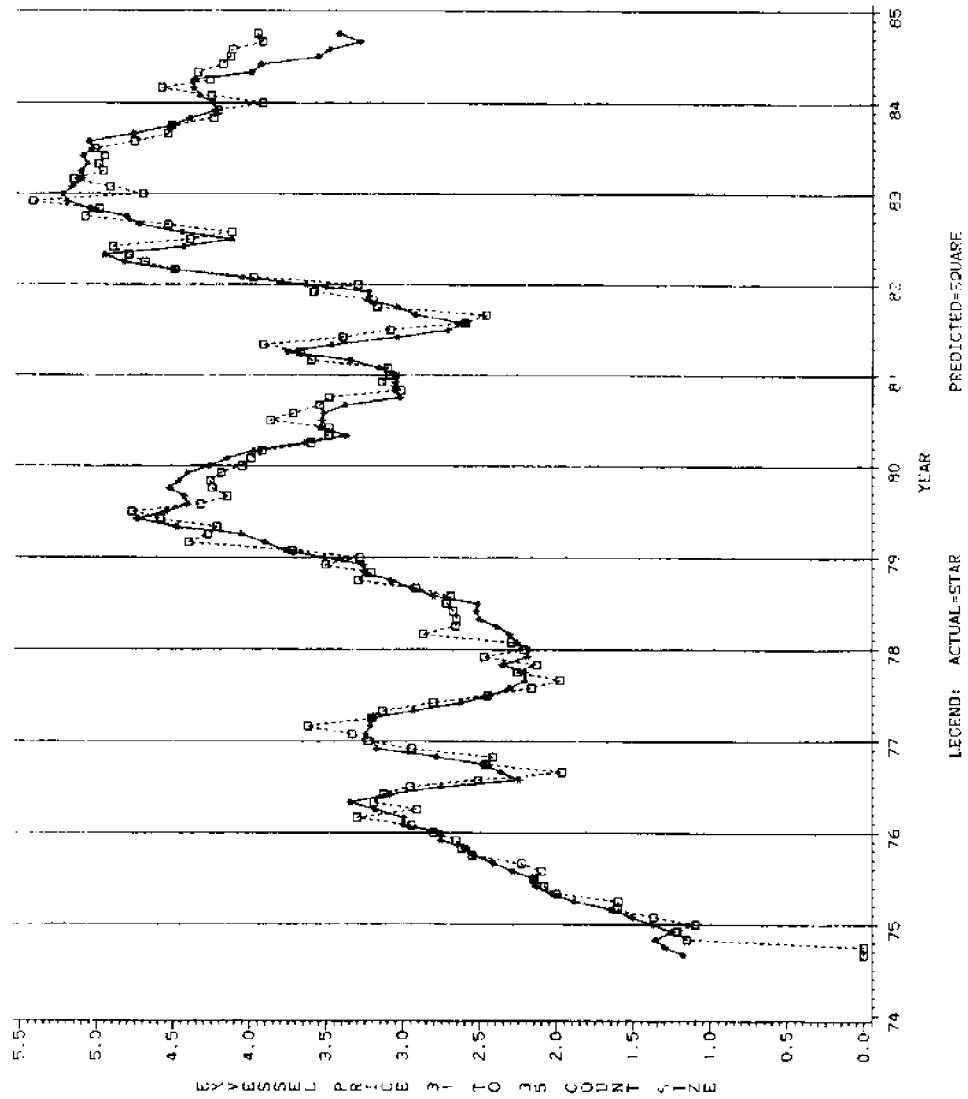


Figure 3. Actual and Model I forecast of 31-35 count exvessel price.

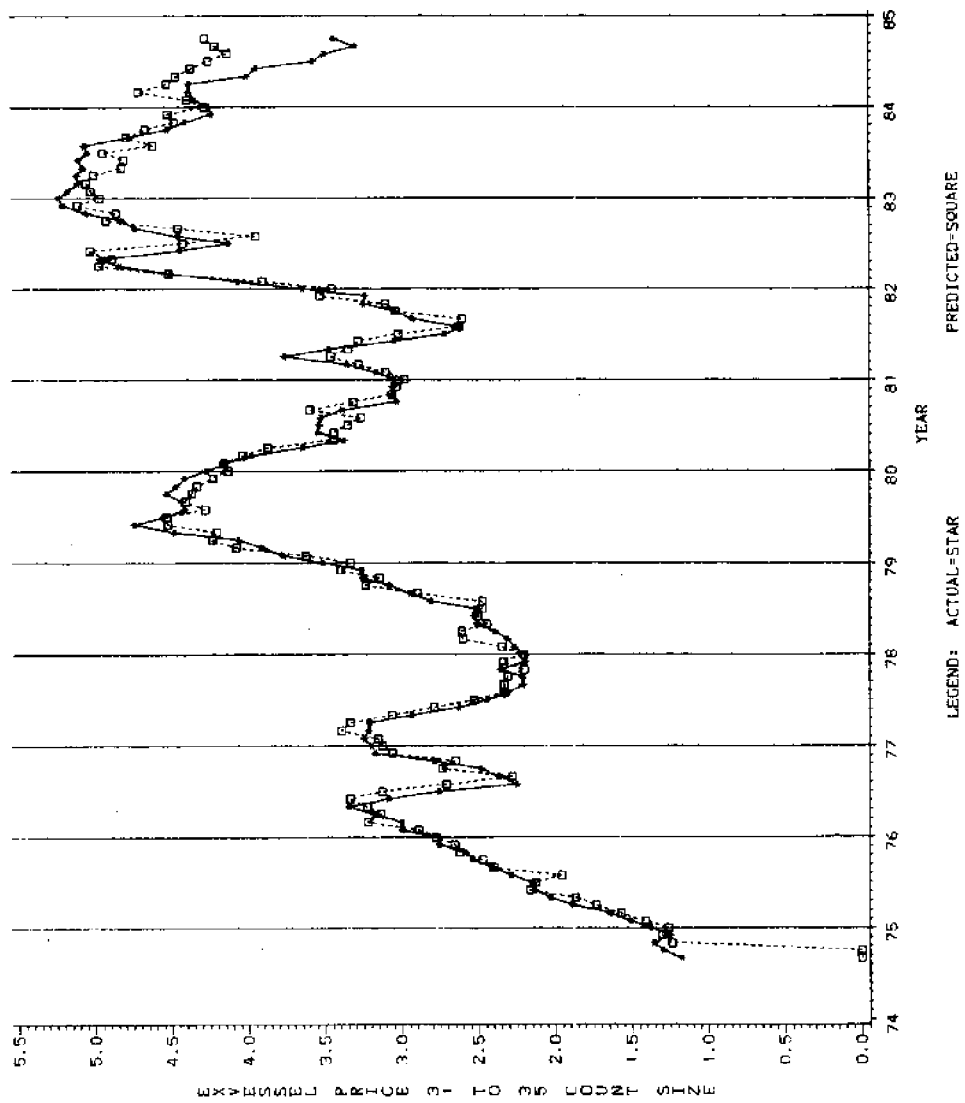


Figure 4. Actual and Model II forecast of 31-35 count exvessel price.

calculated over the ex post forecast period only. Since the model is intended to forecast prices, only these errors will be presented.

Table 6. Ex Post RMS Forecast Errors

VARIABLE	MODEL I	MODEL II
Wholesale Price	.3929	.6263
Exvessel Price	.5098	.6851

It is interesting to note that even though Model II's overall rms error for wholesale prices was lower than Model I's, the situation was reversed for the ex post error. Model I was selected on the basis of its ability to predict the turn in exvessel prices and its lower ex post rms error. Table 7 contains the estimated coefficients of Model I. A detailed discussion of a similar model can be found in Thompson, et al. (1985). For the purposes of this paper, the forecasts that this model can generate are more important.

Forecasting with the Model

Before a forecast can be generated from the model, it is necessary to forecast all of the exogenous variables. Some are simple to forecast. The dummy variables are forecasted once the time of the year is known. Some of the variables were more problematic. The average precipitation and temperature for each month were used as the predicted values of these variables. It was necessary to use this technique because no long-term forecasts of these variables were available. The forecasts for prime interest rate and price of diesel fuel can be obtained from Data Resources Incorporated or The Wharton econometric model of the U.S. economy. Exchange rate was predicted by another econometric model. The forecast generated by Model I is depicted in Figure 5. The forecast generated predicts a rapid increase in exvessel price¹⁴ of \$1.44 a pound (from \$3.55 to \$4.99) in the six months from November 1984 to April of 1985.

An econometric model is a tool that should be used to supplement judgment, not replace the thought process. It is important to remember that, simply because this forecast is computer-generated, it is not without error. It is unfortunate that it is not a simple matter to place

¹⁴The wholesale price forecasts were similar, rising from \$4.23 to \$6.03 a pound in the same six-month period.

Table 7. Estimated Coefficients and t-Ratios from Model I

Equations	Intercept	St_{t-1}	I	AC	P	P_{t-1}	PW	PW_{t-1}	PW_{t-2}	L	R	X_{t-2}	IMD
PW	0.465 (2.331)	-2.964×10^{-6} (-1.745)	-3.117×10^5 (-2.792)	2.415×10^{-5} (3.192)	0.793 (4.493)	0.318 (1.818)							
P	-0.113 (-1.086)						0.9158 (6.888)	-3.911×10^{-3} (-0.0314)		-8.263×10^{-6} (-1.963)	-0.0112 (-2.461)		
I	7518.087 (2.599)								1838.0 (5.467)			20.917 (2.455)	5993.56 (7.030)
L	1106.424 (0.408)												
TR	7378.12 (-3.217)				185.778 (0.310)					2.641 (14.571)			
St	-5954.57 (-4.577)	0.982 (73.568)	0.851 (14.295)	-0.710 (-11.160)						0.740 (20.396)			
AC	16125.42 (8.596)						-545.172 (-0.911)						

Table 7. (continued)

PR _{t-2}	T _{t-2}	TR	E	F	AQUA	Q2	Q3	Q4
					-0.004 (-0.805)	0.109 (-1.352)	-0.253 (-2.976)	0.010 (0.127)
						0.024 (0.322)	0.136 (1.544)	0.074 (0.977)
						-858.601 (-0.860)	1481.935 (1.466)	7192.091 (7.135)
-68.968 (-1.531)	31.514 (0.915)	0.340 (13.754)				-132.161 (-0.130)	5585.838 (4.920)	2865.705 (2.708)
				393.064 (0.235)		369.398 (0.121)	-15546.7 (-4.277)	-9131.0 (-2.964)
			2.665 (7.209)			1602.637 (1.198)	6035.818 (4.260)	5665.837 (4.183)

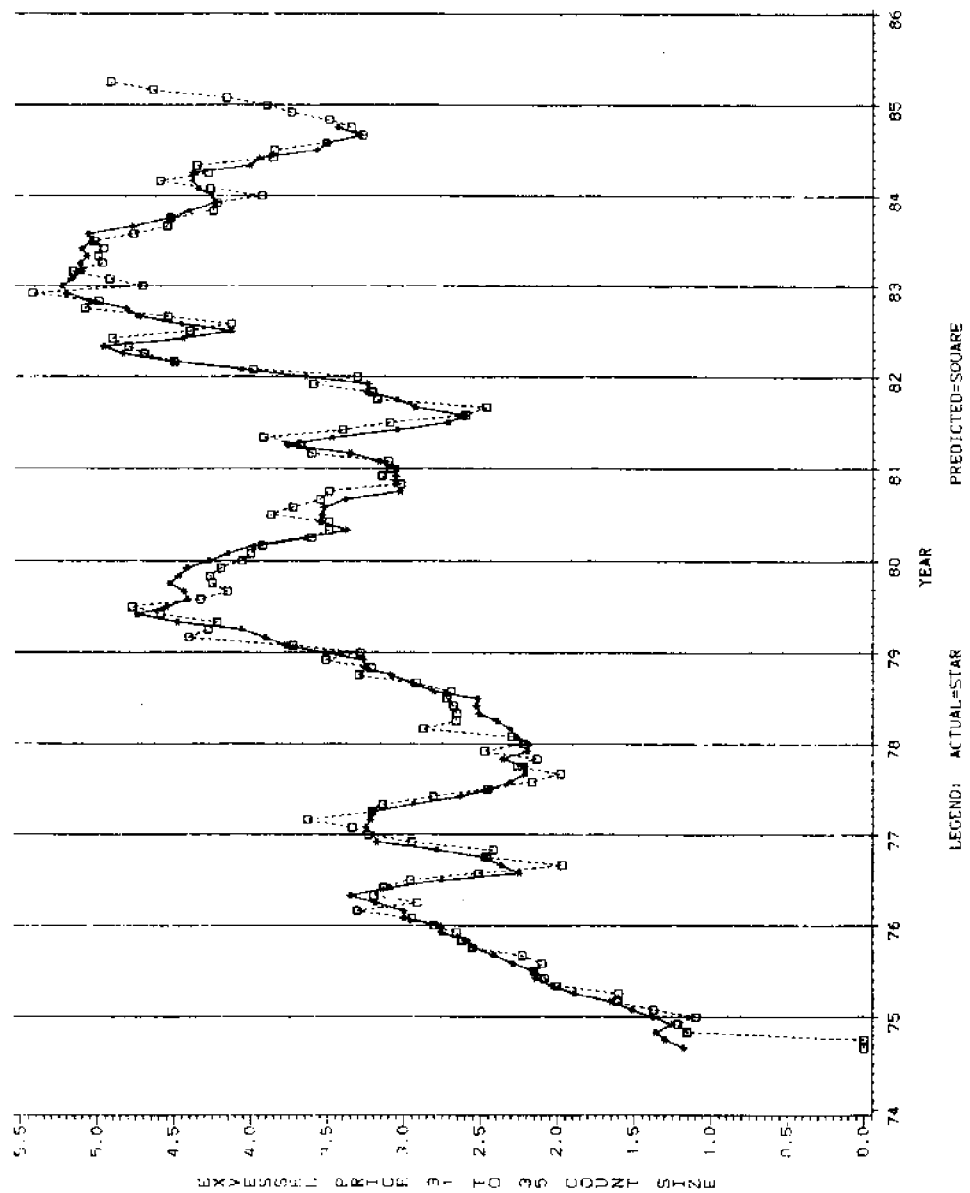


Figure 5. Actual and Model I forecasts for 31-35 count exvessel price, including 11/85 to 4/86 ex ante price forecast.

confidence intervals around the forecast, but other judgmental methods can be used.¹⁵

While the model predicts a large increase from November to April, it is not an unprecedented large increase. The same periods for 1977-78, 1978-79, and 1981-82 have similar increases. By examining the historical price time series (Figure 6), it can be seen that at the bottom of downward price movements (August 1976, October 1977 through January 1978, August 1981, and July 1982) wholesale price had fallen more rapidly than exvessel price, causing the margin to decrease. This appears to have occurred once more in 1984.

Other factors that will affect shrimp prices not covered explicitly in the model include the overall economy and Lent. The economy, while not experiencing the rapid growth of early 1984, is still growing, increasing the consumption of foods such as shrimp, Lent historically increases the consumption of seafood.

The preceding are examples of the types of judgmental factors a manager can employ to supplement an econometric model. It is important not to accept a model's forecasts blindly.

The Aquaculture Model

It was decided that the model could be further modified in order to analyze the effects that cultivated shrimp have on the U.S. shrimp market. Unfortunately, the data needed to do this are not available. While it has been estimated that in 1983 approximately 15 percent of U.S. shrimp imports were from aquaculture, exact weights are not known. Most pond-grown shrimp from Ecuador are grown to a size between 26 and 40 count. This changes the composition of the shrimp harvest. The poundage of shrimp in the 26- to 40-count size range is higher than it would be if all shrimp were harvested from naturally occurring stock.

The analysis was completed in two steps: a forecast was made of U.S. 26- to 40- count imports and landings, and the model was modified to make this "aquaculture of sizes" exogenous. The aquaculture variable was the imports to landings ratio.

There was no way to use the historical data in order to create the forecast of the aquaculture of sizes; as aquaculture is a new development, there are not enough data to use it for a time series or econometric model. It was decided to use the forecasts presented in Shrimp Situation and Outlook (NMFS, June 1984) as a basis for the aquaculture forecast. The largest estimate of pond-raised shrimp entering the U.S. in the year 1990 was 450 million pounds. This indicated a 75-million-pound increase in 26-to 40-count shrimp per year.

¹⁵Confidence intervals can be "estimated" using Monte Carlo simulation, which was beyond the scope of this study (see Pindyck and Rubinfeld, 1981).

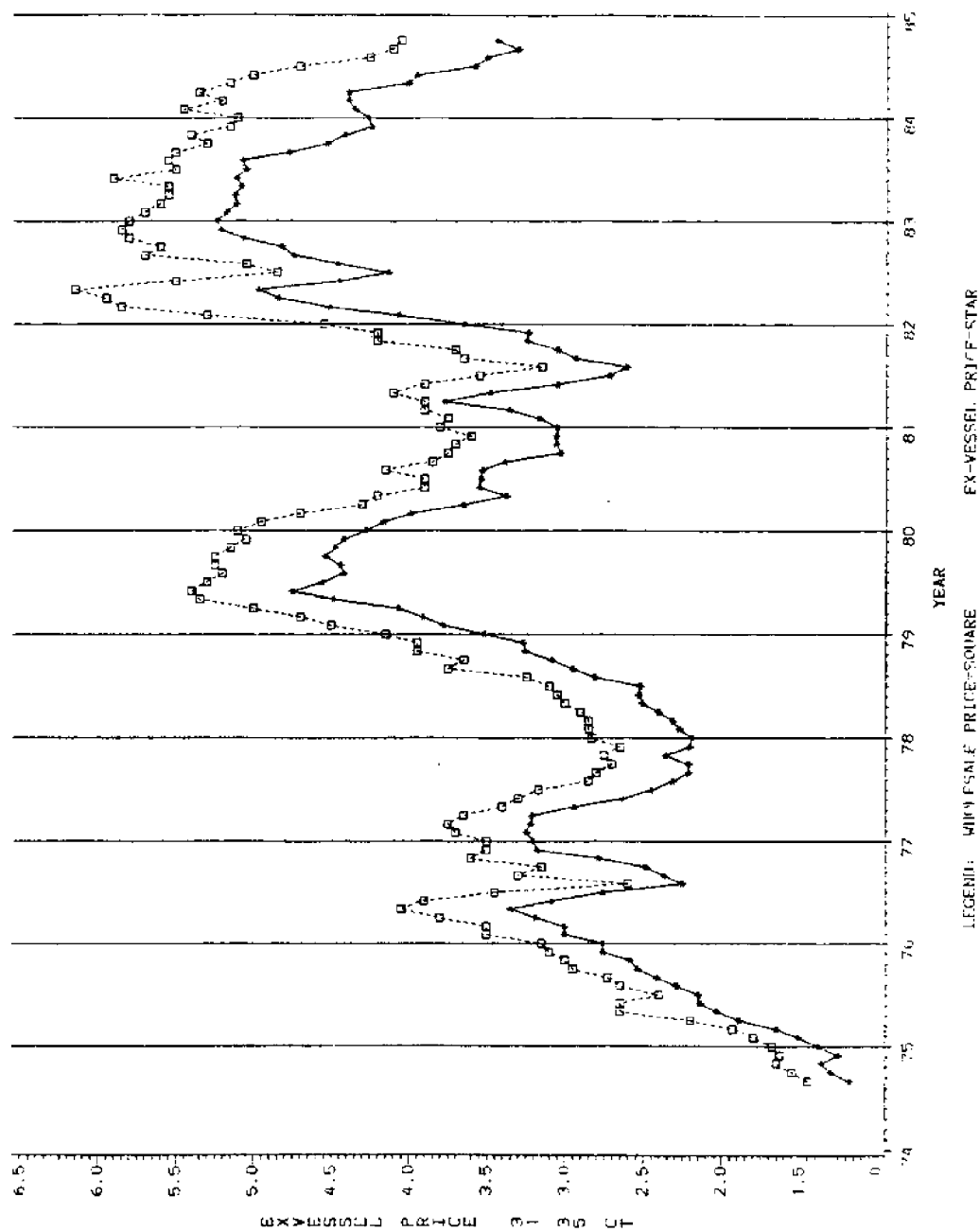


Figure 6. Wholesale and exvessel price of 31-35 count shrimp from September, 1974 to October, 1984.

The model was modified. The wholesale price equation was changed to:

$$PW = f (St_1, I, Aqua, AC, P, P_1, Q2, Q3, Q4)$$

where:

Aqua = ratio of imports to landings in the
26-40 count size range

and the remaining variables were as previously defined.

No other equation in the model was modified.

Table 8 contains the estimated coefficients of the aquacluster model. The forecast for the model is presented in Figure 7. It is interesting that both econometric models produce very similar forecasts.

Summary and Conclusions

Forecasting techniques range from simple extrapolation to complex econometric models. Three separate models were presented in this paper. The time series model, an ARIMA (1,1,1), tracked the data well, but did not do well in forecasting turning points in the data; nor did the ex post forecast simulate the price series closely. Although the model has simple data requirements (the price time series), there are few statistical tests to guide the forecaster through the construction of the model.

The two econometric models required more data. They do allow for the testing of economic relationships and hypotheses.¹⁶ Econometric models are developed with the underlying cause and effect relationships as a guide. Both models followed the price data well. Model I was able to pick up turning points in an ex post forecast period.

All three models predict an upturn in prices. The models were supported by other facts, such as an improved economy and the coming of Lent.

Recommendations for Further Research

This paper has stressed the use of forecasting models as tools to aid the judgment of those persons involved in the shrimp industry. A model should be assessed by how well it aids the judgmental process, not by whether it predicts prices exactly. In order to accomplish this, it is necessary to have a committee of industry members forecast prices that can be compared with the prices predicted by the model--a unique method of testing the model's forecasting ability.

¹⁶For example, the effect on price of aquacultured imports.

Table 8. Estimated Coefficients and t-Ratios of the Aquaculture Model

Equations	Intercept	St_{t-1}	I	AC	P	P_{t-1}	PW	PW_{t-1}	PW_{t-2}	L	R	X_{t-2}	IMD
PW	0.481 (2.444)	-2.827×10^{-6} (-1.683)	-2.644×10^{-5} (-2.289)	2.039×10^{-5} (2.945)	0.848 (4.817)	0.265 (1.522)							
P	-0.115 (-1.158)						0.848 (6.920)	0.062 (0.540)		-8.650×10^{-6} (-2.264)	-9.748×10^{-3} (-2.122)		
I	7113.1 (2.447)								1894.069 (5.608)			21.784 (2.541)	6189.784 (7.169)
L	1515.625 (0.811)												
TR	-8041.7 (-3.646)				85.833 (0.172)					2.770 (14.859)			
ST	-5476.85 (-4.328)	0.985 (74.095)	0.844 (14.867)	-0.734 (-12.248)						0.758 (20.912)			
AC	15523.81 (8.045)						-907.517 (-1.446)						

Table 8... (continued)

PR _{t-2}	T _{t-2}	TR	E	F	Q2	Q3	Q4
					-0.110 (-1.258)	-0.250 (-2.651)	0.042 (0.568)
					0.024 (0.297)	0.135 (1.414)	0.073 (0.901)
					-849.056 (-0.852)	1750.051 (1.749)	7191.742 (7.143)
-97.887 (-1.654)	41.826 (0.813)	0.350 (10.159)			56.279 (-0.051)	5577.779 (4.481)	2361.891 (2.015)
				-340.908 (-0.170)	66.485 (0.023)	-14944.1 (-4.294)	-7787.62 (-2.622)
			2.316 (6.604)		1460.549 (1.107)	6431.546 (4.600)	5576.165 (4.149)

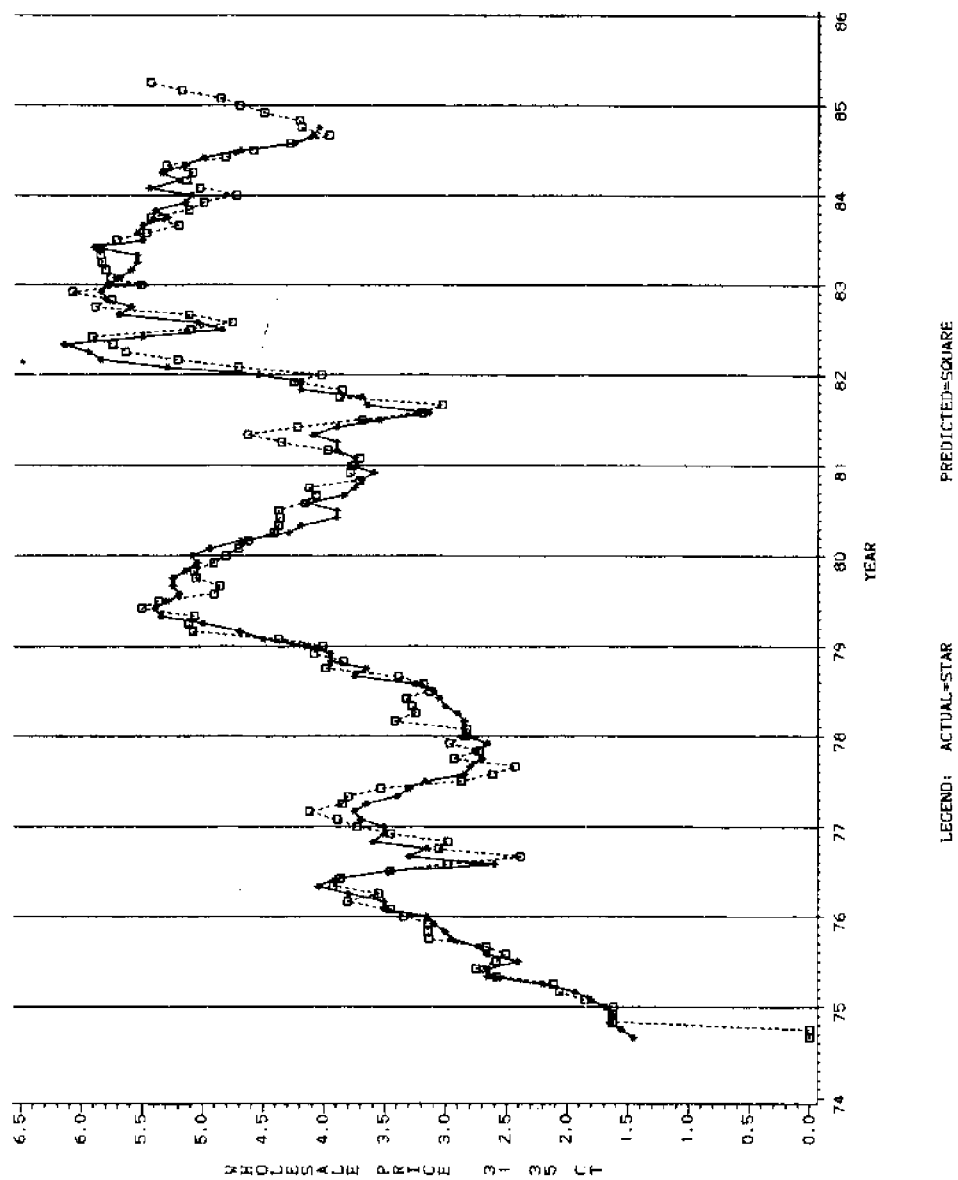


Figure 7. Actual and aquaculture model forecasts for 31-35 count wholesale shrimp price, including 11/85 to 4/86 ex ante forecast.

Further refinement of the model is needed in the areas of (1) exchange rates and their effects on imports, (2) time periods of lags and their structure (linear vs. geometric), (3) model structure--the model is now linear. It is possible to estimate a nonlinear model, and this should be investigated, and (4) further investigation of the aquaculture model. Although estimation of other aquaculture models was attempted, the presented model was the most successful. There is room for improvement.

The researchers plan to continue updating and refining the econometric and time series models so that forecasts can be provided to industry and government.

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THE DEMAND FOR MAJOR REEF FISH SPECIES IN THE GULF & SOUTH
ATLANTIC REGIONS OF THE UNITED STATES

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INTRODUCTION

There are numerous species comprising the tropical and subtropical reef fish complex in the Southeastern section of the United States including snapper, grouper, sea bass, tilefish, jacks, triggerfish, wrasses, grunts, porgies, and sand perch. However, of all these species, only snapper, grouper, and sea bass have traditionally been targeted by the commercial fishing sector and hence qualify for being included within the Management Unit of the Gulf of Mexico Fishery Management Council.

Combined, landings of grouper and snapper account for essentially all the value of reef fish landings within the jurisdiction of the Gulf of Mexico Fishery Management Council and most of the value of reef fish landings within the jurisdiction of the South Atlantic Management Council. Traditionally, landings of grouper in the Gulf Region of the United States have accounted for about eighty to ninety percent of total U.S. landings of grouper while the Gulf Region landings of snapper have accounted for about the same percentage of total U.S. landings of snapper. The South Atlantic Region of the United States accounts for virtually all of the remaining landings of both grouper and snapper with only sporadic and minimal catches of these species reported in the Pacific and Hawaiian Regions of the United States.

Within the Gulf Region of the United States, the Florida West Coast records the majority of the landings of grouper and snapper with only a minor volume of these species landed in the remaining Gulf States. Furthermore, the average price per pound associated with these species on the Florida West Coast exceeds that reported for the other states in the Gulf Region, apparently the result of differences in market outlets and quality (Cato and Prochaska). Though reported landings of grouper and snapper in the Gulf States other than Florida are relatively minor, the importance of the reef stocks in these states to the condition of the reef fish commercial fishing sector may be substantially underestimated. An undetermined amount of grouper and snapper apparently are harvested outside Florida's waters but transported directly to Florida for further

processing and/or distribution without passing through coastal dealers in other Gulf States. As such, the catch goes unrecorded in the landing statistics of the state in which the fish were actually caught. For example, it has been reported that over 450,000 pounds of grouper and red snapper valued at almost \$2 million are taken from around oil platforms off the Louisiana coast yearly by more than 100 Florida vessels (Anonymous). Apparently, very little of this product is channeled through Louisiana wholesalers/dealers since reported commercial landings of grouper and red snapper were valued at only \$725,000 in 1982 and \$1.2 million in 1983.

The remainder of the paper proceeds as follows. First, U.S. commercial landings, values, dockside prices, and imports of grouper and snapper into the United States are presented and discussed. Second, an analysis conducted to determine those factors and to quantify the effects of those factors on prices received by commercial fishermen in the United States are presented and discussed. Finally, a profile developed from a sample of almost 15,000 households is presented to examine those factors differentiating households consuming the major reef fish species at home with those not consuming these species at home. Additionally, in this section, differences in consumption and expenditures on grouper and snapper among different groups of households are examined.

VOLUME, VALUE, AND IMPORTS OF GROUPER AND SNAPPER

Combined commercial landings of grouper and snapper in the United States have averaged just over twenty million pounds annually during the 1960-82 period. After peaking at almost twenty-six million pounds in 1965, combined yearly landings of grouper and snapper began a downward trend leveling off in 1977 when a minimum of about fifteen million pounds were harvested in the United States (Figure 1). With the onset of bottom longlining for grouper and snapper in the Gulf Region in the late 1970's combined commercial landings of these species increased, and exceeded twenty-five million pounds in 1982 for the first time since 1965.

In the early 1960's, commercial landings of grouper averaged slightly more than half that of snapper landings (Figure 1). However, after 1965, commercial landings of snapper began to decline while commercial landings of grouper remained relatively constant at approximately eight million pounds per year. The declining snapper landings in conjunction with the relatively stable grouper landings resulted in a narrowing of the difference in the reported landings of grouper and snapper and in 1979 for the first time since before 1960, domestic landings of grouper exceeded that of snapper. Since 1979, the excess of grouper landings over landings of snapper has increased, equalling more than four million pounds in 1982.

As the commercial landings of snapper began to decline in the mid 1960's, the composition of snapper species comprising the total catch changed decisively. During the 1960-65 period, commercial landings of red snapper averaged just over eighty-eight percent of the total commercial landings of snapper (Figure 1). During the 1977-82 period,

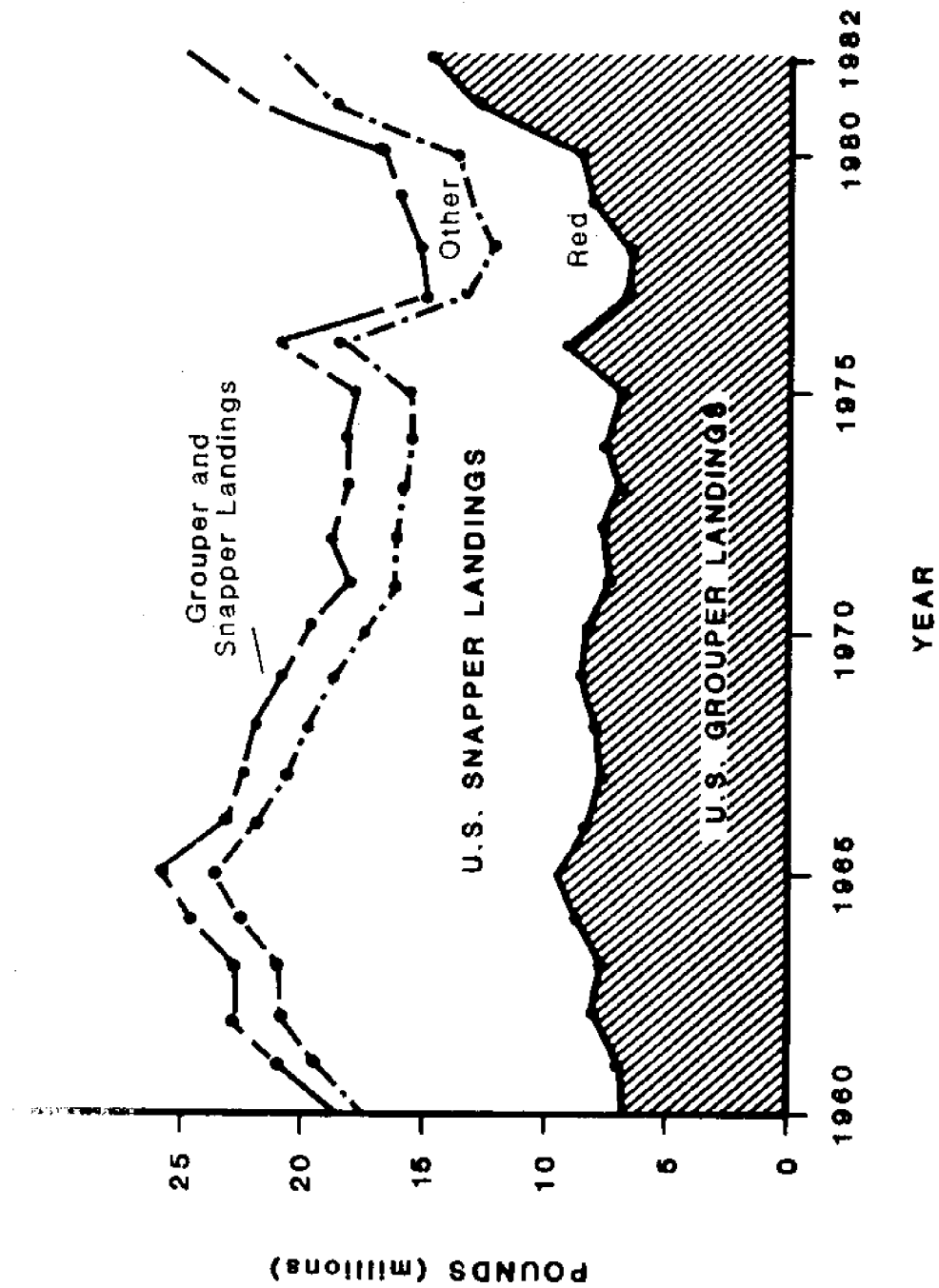


Figure 1. U.S. Commercial Landings of Grouper and Snapper, 1960-82.

this percentage had fallen to approximately sixty-five percent. As indicated by the long run trend in the composition of snapper landings, whereas the catch of red snapper was at one time of prime importance to the commercial fishing sector, landings of such species as mutton, mangrove, vermillion, and yellowtail snapper are becoming increasingly important.

The dockside value of commercial landings of grouper and snapper has averaged \$10.4 million annually during the 1960-82 period (Figure 2). Higher average yearly landings together with a higher average price per pound has resulted in the yearly value of snapper landings (\$7 million) averaging about twice that of grouper landings (\$3.4 million). The dockside value of grouper landings has increased approximately 860 percent during the 1960-65 through 1977-82 period, from approximately \$875,000 annually to almost \$8.5 million annually (Figure 2). This increased value is the result of two factors; first, increased landings (Figure 1) and second, an increase in the dockside price per pound (Figure 3). Whereas, the consumer price index, a measure of the general price level of all goods and services, increased 155 percent during the 1960-65 through 1977-82 time period, the weighted average price per pound of grouper during this period increased just over 700 percent; more than quadruple that of the consumer price index. The factors leading to the increases in the dockside grouper price are discussed in the next section.

Like the dockside value of grouper, the value of snapper landed in the United States has trended upward at a rapid rate over the time period considered (Figure 2). Averaging almost \$4.0 million annually during the 1960-65 period, the dockside value of snapper landings increased to an average of over \$11.7 million annually during the 1977-82 period. Unlike the increased value of grouper landings, the increased value of snapper landings cannot be attributed to increased volume. Rather, the increased value of snapper landings is due entirely to an increase in the per pound price for snapper at dockside. Averaging \$0.27 per pound during the 1960-65 period, the average per pound price for snapper increased consistently throughout the twenty-three year time period under consideration, and averaged \$1.45 during the 1977-82 period (Figure 3). This translates to a 438 percent increase in the dockside price of snapper or a price increase approximately three times greater than the increase in the consumer price index. In the early 1960's, the average per pound price for red snapper and that of other snapper species was nearly equivalent (Figure 3). However, after the mid 1960's in association with decreased red snapper landings and increased landings of other types of snapper, the price per pound for red snapper increased at a relatively faster rate than that for other snapper. The difference in price between the two types of snapper reached a maximum of almost \$0.40 per pound in 1981 (Figure 3). Those factors determining the dockside price of snapper are examined in the following section.

Imports of grouper and snapper throughout the twenty-three year study period have been considerably more erratic than that of the commercial landings of these species. Grouper imports, after trending

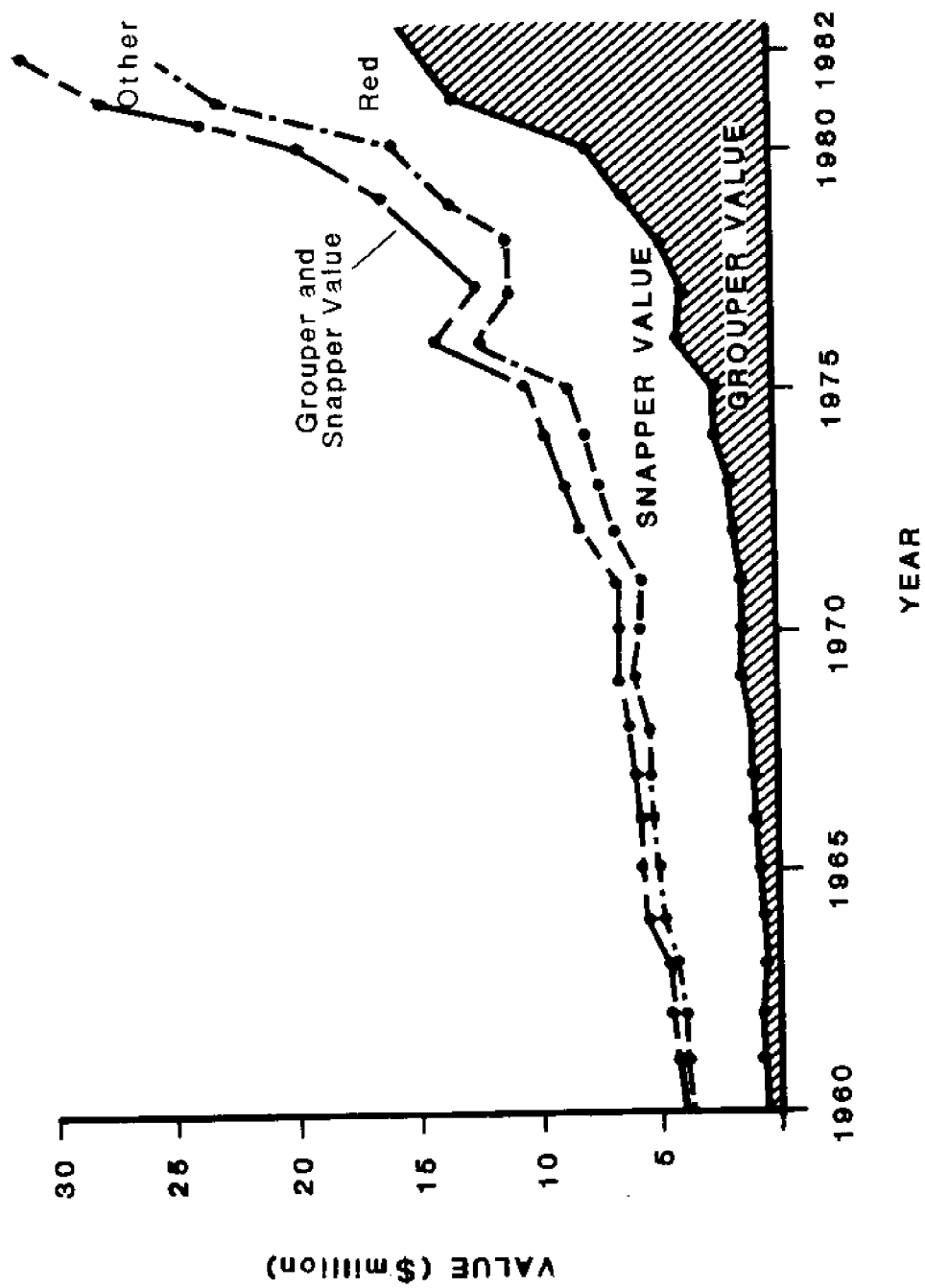


Figure 2. U.S. Dockside Value of Grouper and Snapper, 1960-82.

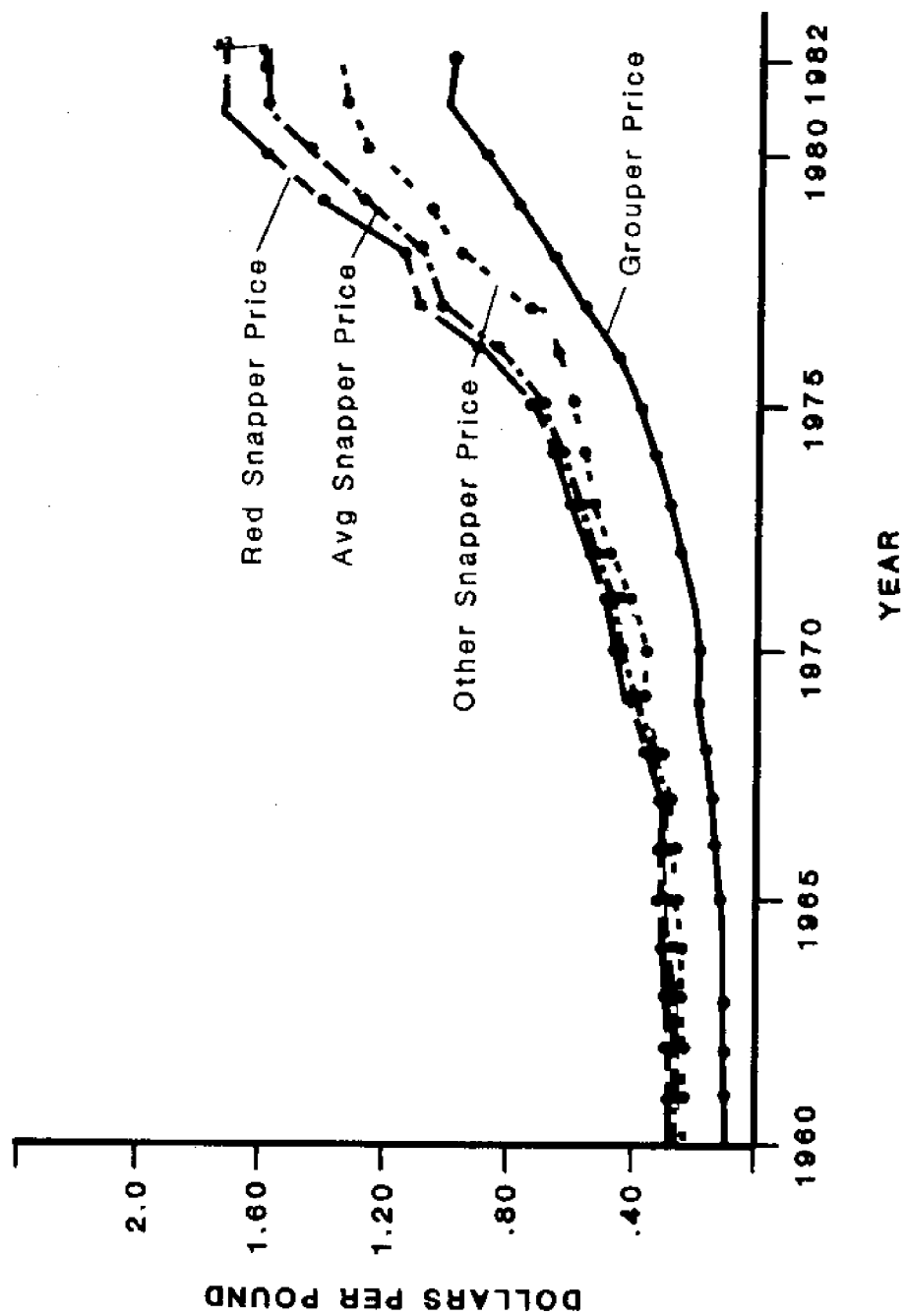


Figure 3. U.S. Dockside Prices for Grouper and Snapper, 1960-82.

upwards at a rapid rate during the early 1960's fell almost ninety percent between 1966 and 1967, from close to seven million pounds (whole weight basis) to less than eight-hundred thousand pounds (Figure 4). Similarly, snapper imports after trending upwards throughout the early 1960's fell almost thirty-five percent between 1966 and 1967, from over two million pounds (whole weight basis) to less than 1.4 million pounds (Figure 4). The decline in imports of grouper and snapper between 1966 and 1967 coincided with the announcement by the Catholic Bishops of the United States in December 1966 which essentially ended the mandatory meatless Friday's observed by the Catholic Population. After remaining relatively constant for the next several years at less than a million pounds, imports of grouper increased considerably in 1972 when in excess of eight million pounds of the product were imported into the United States. Imports of grouper remained at a relatively high level until the late 1970's at which time the increase in domestic landings resulting from longlining decreased the demand for imports. After remaining relatively constant for several years after the Catholic Bishops announcement, imports of snapper increased significantly in 1973 when 4.6 million pounds were imported. Imports of snapper have averaged 4.9 million pounds annually since that time ranging from 4.0 to 6.0 million pounds per year.

DOCKSIDE PRICE DETERMINATION FOR GROUPER AND SNAPPER

The price that fishermen receive for their product is a derived demand associated with the price consumers are willing to pay for that product in the market place. In turn, the price consumers are willing to pay for that product in the market place depends on factors such as income, the availability of substitute products, institutional constraints, and overall desire. Assuming domestic landings to be relatively unresponsive to dockside price, at least in the short run, dockside price rather than landings is expected to vary with changes in the previously mentioned factors. Recognizing this condition, the dockside prices for grouper and snapper were specified to be a function of the following variables:

$$P_{it} = f(Q_{it}, I_{it}, INC_t, D_t) \quad \begin{matrix} (i = 1, 2) \\ \text{where,} \quad (t = 1, 2, \dots, 23) \end{matrix}$$

P_{it} = Average yearly dockside price of grouper in year t if $i = 1$
or snapper if $i = 2$

Q_{it} = U.S. commercial landings of grouper in year t if $i = 1$ or
snappers if $i = 2$ (thousands of pounds)

I_{it} = imports of grouper into the Gulf Region of the United States
in year t if $i = 1$ or snapper if $i = 2$ (thousands of
pounds whole weight basis)

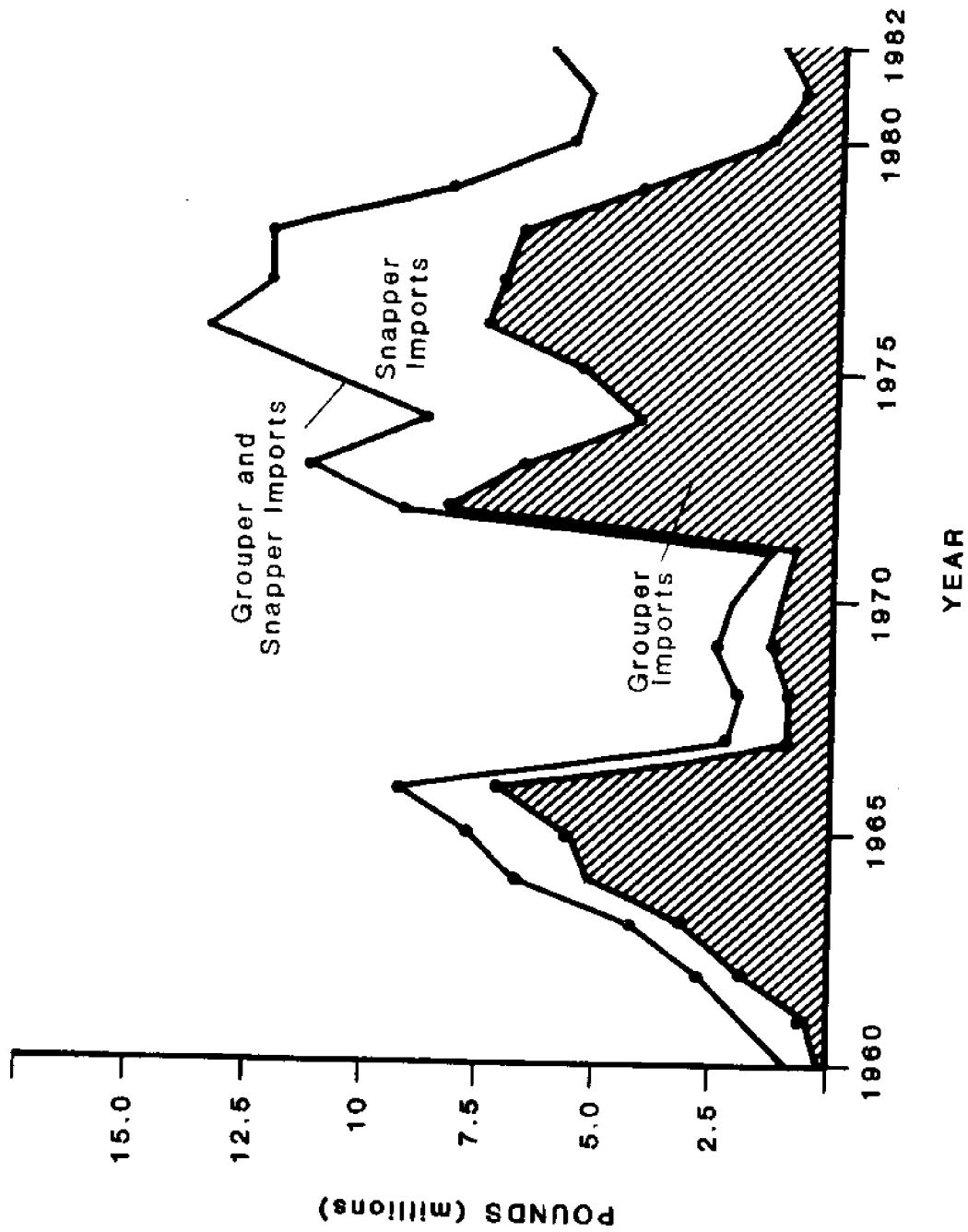


Figure 4. Imports of Grouper and Snapper into the Gulf Region of the United States (Whole Weight), 1960-82.

INC_t = United States disposable income in year t (billions of dollars)

D_t = a binary variable equalling one if before 1967 and zero otherwise, representing a change in the institutional constraints associated with the Catholic Bishops announcement in December 1966.

The dockside prices of grouper and snapper are hypothesized to be negative related to their respective landings. Imports of grouper and snapper representing a substitute for domestic landings are also hypothesized to affect dockside prices in a negative manner. Assuming grouper and snapper to be considered normal goods in the market place, the dockside prices of grouper and snapper are hypothesized to be positively related to disposable income. Finally, an end to the "meatless Friday policy", is expected to have a negative influence on the dockside prices for grouper and snapper since it is hypothesized to result in a decline in demand.

The regression analyses were estimated using a double log functional form for the two equations. Furthermore, given the expected similarity between the demand for grouper and the demand for snapper, the error terms between the two estimated equations were hypothesized to react in a similar fashion and hence be highly correlated. The correlation of the error terms was used to improve the efficiency of the parameter estimates via seemingly unrelated regression techniques (see Maddala for a discussion of this technique). The estimated parameters associated with the two equations are presented in Table 1.

Table 1. Estimated United States Dockside Price Equations for Grouper and Snapper.

	<u>Intercept</u>	<u>Qi</u>	<u>Ii</u>	<u>INC</u>	<u>D</u>	<u>R²</u>	<u>D.W.</u> ^b
Grouper	-7.797* (.8846) ^a	-0.4614* (.1123)	-0.0470* (.0144)	1.6314* (.0599)	0.2659* (.0658)	.991	2.04
Snapper	-4.291* (.8240)	-0.3698* (.0697)	-0.0152 (.0155)	1.0797* (.0424)	0.1437* (.0291)	.997	1.94

^aAsymptotic standard errors are given in parentheses.

^bDurbin-Watson statistics and R^2 's refer to the first stage of the analyses (i.e., OLS estimates).

* Indicates that parameter estimate is significant at the ninety-five percent level.

Statistically, both estimated price equations appear very satisfactory. As indicated by the R^2 's associated with each equation, more than 99 percent of the variation in the dockside prices of grouper and snapper have been explained by the variables entered into the respective models. As indicated by the Durbin Watson statistics, no apparent serial correlation exists in either estimated price equation. Furthermore, all but one of the estimated parameters, imports of snapper, were found to be statistically significant at the 95 percent confidence level and all parameter estimates conform to theoretical expectations with respect to the estimated parameter signs.

Dockside prices for grouper and snapper were estimated to be negatively related to the domestic commercial landings of the respective species. The results of the regression analyses indicated that a ten percent increase (decrease) in U.S. commercial landings of grouper results in a 4.6 percent change in the dockside price for grouper in the opposite direction. Similarly, a ten percent increase (decrease) in the U.S. commercial landings of snapper results in a 3.7 percent change in the dockside price of snapper in the opposite direction.

Though it is not yet definite that the Gulf of Mexico reef fish commercial industry is overcapitalized the relatively unresponsive changes in the dockside prices of grouper and snapper with respect to changes in their respective domestic landings will help lead to such a situation. Expansion or retraction of industry effort in a commercial fishery can be related to the excess of revenues per unit of additional effort over costs per unit of additional effort. As industry effort expands, revenues per unit of effort vary for two reasons. First, the catch per unit of effort declines with additional effort. Second, the price of the output declines as output is increased via increased effort. As long as the revenues from an additional unit of effort exceed the associated costs, increases in industry effort are expected. The analyses suggests that dockside prices of grouper and snapper react relatively little to changes in the commercial catch of these species. Thus as long as industry catch increases with increases in industry effort, industry revenue will increase. As long as the increases in revenue generated from increases in the catch of grouper and snapper exceed the costs from the additional effort required for the additional catch, effort will increase.

Imports of grouper into the Gulf Region, although statistically significant in explaining the dockside price of grouper, are economically of little importance in the determination of the dockside price of grouper. The parameter estimate associated with the imports of grouper suggests that a ten percent change in the level of grouper imports (whole weight basis) results in a change in price in the opposite direction of only five-tenths of one percent. Imports of snapper into the Gulf Region (whole weight basis) apparently have even a smaller effect on dockside prices of snapper than do the imports of grouper on dockside grouper prices. As suggested by the results of the regression analyses, a ten percent increase (decrease) in snapper imports results in a decrease

(increase) in the dockside price of snapper in the United States of less than two-tenths of one percent. The possible reasons for the relatively minor effect of grouper and snapper imports on their respective dockside prices are numerous and varied. One of the leading factors probably contributing to the relatively small impact that imports have on the domestic dockside prices relates to quality and product form differences between the domestic products and the imported products. Domestic production of grouper and snapper is generally channelled through coastal dealers to wholesalers or retailers very quickly in either a fresh whole iced or fresh fillet basis (Prochaska and Keithly [1978] and unpublished data collected by Prochaska and Keithly). Less than two percent of the domestic landings of grouper and snapper channelled through coastal dealers in the Gulf of Mexico is frozen when leaving the first handler. By comparison, upwards to eighty percent of the grouper and fifty percent of the snappers entering the United States through the import market enter in a frozen form (NMFS, unpublished data). Furthermore, the imported grouper and snapper products that enter into the United States may be of lower quality than that of the domestic products due to less stringent processing and transportation procedures practiced in the Central and South American countries when compared to the procedures practiced in the United States.

Disposable income in the United States is an extremely important determinant of the dockside prices for grouper and snapper. A ten percent increase in U.S. disposable income was estimated to result in a 16.3 percent increase in the dockside price of grouper and a 10.8 percent increase in the dockside price of snapper. These relatively high estimates of the effect of disposable income on prices suggests that both grouper and snapper are considered by the consumers as preferred items. Much of the reason for the high dockside price responsiveness of grouper and snapper to changes in income relates to the high volume of restaurant trade in these products. Away from home consumption is much more responsive to changes in income than at home consumption. As restaurant trade increases with increases in disposable income, demand for the more expensive and higher quality fishery products, grouper and snapper being two examples, also increases at a pronounced rate.

The U.S. Catholic Bishops announcement in December 1966 ending the obligatory meatless Fridays for the Catholic Population in the United States was found to have pronounced effects on the dockside prices of grouper and snapper. As a result of the announcement, the dockside prices of grouper and snapper were estimated to have declined by 27 percent and 14 percent respectively, holding all other factors constant. However, at that time in the aggregate other factors did change. Therefore, the net effect at that time was no decline in the dockside prices of either grouper or snapper (Figure 3). Based upon the above models, it is hypothesized that the announcement had the effect of creating an excess supply of grouper and snapper in the market place at the old equilibrium prices. Rather than witnessing a drop in price as a result of the excess supply, imports of grouper and snapper were sharply curtailed (Figure 4). The curtailment in imports in conjunction with an

increasing disposable income and a slight drop in domestic landings of grouper and snapper led to an increase in the prices of grouper and snapper after the announcement rather than a decrease as would otherwise have been the case.

As a summary to this section, it should first be mentioned that the dockside prices of grouper and snapper are affected by the same general set of factors. These factors include the domestic landings of the respective species, imports of the respective species, disposable income, and a binary variable representing the Catholic Bishops announcement. The greater price increase of grouper relative to snapper over the twenty-three year study period results from the greater effect that disposable income has on the dockside price of grouper than snapper together with the change in composition of snapper landings. Finally, given the relatively minor impact that imports of grouper and snapper have on their respective dockside prices and the reported overfishing of the domestic stocks, the dockside prices of these species can be expected to advance steadily with increases in disposable income.

AT HOME CONSUMPTION OF GROUPER AND SNAPPER

The United States Department of Agriculture conducted a nationwide food consumption survey during 1977 and 1978 with the purpose of obtaining information on the quantities and cost of food products consumed at home during a one week's period by a representative sample of households. The survey, conducted from April 1977 through March 1978 encompassed almost 15,000 households selected to represent the universe of households in the 48 contiguous states. Selected information pertaining to the consumption and expenditures on grouper and snapper by these households is summarized in Table 2.

Perhaps the most noteworthy statistic of those presented in Table 2 is that one reflecting the extremely low proportion of households consuming either grouper or snapper at home on a weekly basis. Of the 15,000 households interviewed, only 40 households reported having consumed grouper products at home during the one week period while 83 households reported having consumed snapper products at home during the one week period. Among consuming households, grouper consumption averaged 2.2 pounds per household compared to snapper consumption of 2.0 pounds per household. The average retail price of snapper during the 1977-78 survey period equalled \$1.64 per pound compared to \$1.35 per pound for grouper. The \$0.29 per pound observed retail price differential between the two species is close to that observed at the dockside level during the 1977-78 period (Figure 3).

More specifically, the descriptive statistics suggest that consumption of grouper and snapper among households living in the central city areas of the country is more frequent than in other levels of urbanization. Similarly, frequency of consumption, though not the level of consumption, was greatest among those households living in the Western

Table 2. Descriptive Statistics Relating to Weekly
at Home Consumption of Grouper and Snapper

Variable	Grouper				Snapper			
	n	lb.	\$/lb	% con.	n	lb.	\$/lb	% con.
Urbanization:								
Central City	17	2.34	1.38	0.38	40	2.34	1.51	0.90
Suburban	17	2.27	1.37	0.33	31	1.40	1.91	0.59
Non-Metro	6	1.75	1.21	0.11	12	2.50	1.61	0.23
Region:								
Northeast	8	3.66	0.86	0.23	12	1.81	2.18	0.34
North Central	4	2.63	1.20	0.11	12	1.46	1.73	0.32
South	14	2.04	1.18	0.27	28	3.02	1.37	0.54
West	14	1.46	2.38	0.57	31	1.39	1.84	1.26
Before Tax Income:								
(Thousand dollars)								
Less Than 10	10	2.27	1.40	0.23	33	1.46	1.25	0.75
10 to 20	8	1.85	1.45	0.19	18	2.14	1.77	0.43
20 to 30	8	3.03	1.14	0.45	12	1.23	1.88	0.68
30 or Greater	1	5.00	1.00	0.12	8	2.71	1.77	0.95
Household Size:								
One	3	1.42	0.96	0.11	12	2.44	0.95	0.43
Two	15	1.80	1.64	0.33	32	1.55	1.99	0.69
Three	8	2.42	1.29	0.30	19	2.05	1.60	0.72
Four	12	2.62	1.34	0.48	9	2.97	1.22	0.36
Five or more	2	3.38	0.64	0.08	11	2.25	1.82	0.45
Race of Respondent:								
White	25	1.80	1.63	0.20	64	1.78	1.79	0.50
Black	7	3.42	0.89	0.40	16	3.00	1.23	0.92
Other	8	2.49	1.28	1.88	3	1.67	2.12	0.71
Household Life Cycle ^b :								
Young w/o child	4	1.75	1.75	0.23	9	2.21	1.58	0.53
Young w/ child	4	4.29	0.86	0.16	9	1.72	1.91	0.35
Middle-aged w/o child	8	1.68	1.65	0.28	19	1.94	1.49	0.66
Middle-aged w/ child	16	2.42	1.42	0.33	28	2.43	1.50	0.59
Older	8	1.56	1.26	0.26	18	1.48	2.08	0.59
Sample Average:								
Total	40	2.22	1.35	0.27	83	2.01	1.64	0.56

^aEach category may not consist of the same number of households due refusal by certain households to provide certain information.

^bYoung refers to households in which the household head is less than thirty-five years of age. Older refers to those households in which the household head is sixty-five years of age or greater.

Region of the United States. Actual consumption among consuming households was in fact relatively low in the Western Region, perhaps reflecting smaller family sizes or the higher average price.

No relation was noticed between income and consumption of grouper and snapper, perhaps due to the small sample size. Similarly, no relation was noticed between household size and consumption of grouper and snapper. Stratified by race, the statistics indicate that Black households and households of 'Other' ethnic origins are more likely to be at home consumers of grouper and/or snapper than White households and generally tended to consume more. Part of the difference in quantity consumed among the different racial groups probably reflects differences in the level of processing before purchase of the product. Households with children tended to consume more grouper than households without children but not necessarily more often. In the case of snapper consumption, this trend was not apparent.

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DRIED KINGFISH AS A POTENTIAL EXPORT ITEM

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ABSTRACT

Southern Kingfish (Kingfish, Menticirrhus americanus), a shrimp by-catch species, was examined for usefulness as a salted dried product that would make an attractive export item. Mechanically and sun dried varieties were produced and compared. Mechanical drying conditions were at 35°C with maximum dehumidification for two hours which was followed by 30°C and 45% relative humidity until the weight loss reached approximately 40%. This product was compared by chemical and sensory tests to traditional salted dried products. Chemical test results were very similar, except for trimethylamine values which averaged 2.43 mg TMA-N/100 g dry basis for mechanically dried kingfish and ranged from 17 to 144 mg TMA-N/100 g dryweight of traditional products. Venezuelan and American sensory panels rated the kingfish high when compared with traditional products.

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INTRODUCTION

Drying has been a popular method of preserving fish for centuries. According to FAO/NORAD (1982), the utilization of world fish production for human consumption in 1980 as a percentage of live weight equivalent was as follows: 29.3 for fresh, 31.0 for frozen, 19.5 for cured, and 20.2 for canned fish products. It is clear that the drying and canning processes have equal importance for the purpose of conservation at the present time.

Drying fish is the least expensive processing method and perhaps the one that keeps the cost sufficiently low for the end product to be within the reach of people in countries with low per capita income (Sripathy, 1983). The people of these developing countries consume the dried fish as a main source of animal protein in their diet. However, in more and more areas, people are also consuming dried seafoods as gourmet treats and asking for quality products.

Salted dried codfish, for example, is a cherished staple in Portugal, Spain, Italy, and Latin American countries. The most important producing countries include Canada, Norway, and Iceland. Only a small amount of this product is produced in the U. S., mainly for export. In 1983, NMFS organized a salted codfish mission to Brazil and revealed it is a potential market (Rose, 1983). The sales mission found that success is almost assured when a quality product that satisfies a foreign demand is promoted aggressively and intelligently.

Development of salted dried fish products for export using underutilized species caught in the South Atlantic and Gulf of Mexico has been conducted in our pilot plant for two years. Several species such as mullet, black drum, thread herring, and sea trout have been used (Huang and Stephens, 1984). Southern Kingfish (Kingfish, Menticirrhus americanus) is another species identified as underutilized fish and is caught and sold by shrimpers as a by-catch. It was used to develop a salted dried, codfish-like product and tested for acceptance by Hispanic groups in order to determine the possibility of using it as an alternative to codfish.

MATERIALS AND METHODS

Fresh kingfish was purchased from local seafood markets on the same day it was to be brined. All of the fish were scaled and gutted. They were either dressed, headed and dressed, butterfly cut, headed and butterfly cut, or filleted. A saturated brine solution was prepared with the volume based on three liters per kilogram of fish. The fish were immersed in the brine solution for a period of three to five days, with the length of time being dependent on the processed form.

After brining, the fish were placed in our pilot plant dryer. Drying conditions were 35°C and maximum dehumidification for two hours, followed by drying at 30°C and 45% relative humidity until a weight loss of 40 to 45% was reached (Huang and Stephens, 1984).

Some of the butterfly cut fish were laid on metal racks outside and sun dried to compare the quality of dried products. The average drying time was eight hours per day for nine days. The temperature ranged from 10 to 20°C, and relative humidity ranged from 50 to 85%.

In order to match our products with traditional products, two salted dried pollock samples, which were made in Canada and Norway, were obtained from the National Marine Fisheries Service Charleston laboratory and used as controls. Chemical and organoleptic analyses on both kingfish and pollock products were performed.

The chemical analyses consisted of moisture, salt, and fat contents, TBA and TMA values. Except for the measurement of fat content, all the analyses used the same methods which were described in Huang and Stephens (1984).

Fat extraction was performed on a Goldfish fat extractor with ethyl ether as the solvent (AOAC, 1980). The period of extraction was four hours after which the recovered oil was dried at 100°C for 30 minutes, then cooled and weighed.

Organoleptic analysis was conducted on both raw and cooked kingfish and pollock products. Two groups of sensory panelists from the University of Georgia in Athens, Georgia examined the samples. One group consisted of seven Venezuelan students who were familiar with these types of products. Six members of the Georgia Sea Grant program participated as an American panel. The same tests were conducted with the Venezuelan and American panelists. All fish samples were served in individual coded plates.

A traditional Latin American dish called "mojito" was prepared from the dried fish products and used as the cooked sample. The fish were first rehydrated in fresh water, in order to reduce the salt content, then boiled for 40 minutes and manually deboned. The fish flesh was then sautéed in vegetable oil with potatoes, tomatoes, green onions, green and

red peppers, and paprika. During the evaluation of cooked fish, water and unsalted crackers were available for use between samples.

The University of Georgia's Bicentennial Celebration ceremony for the Marine Resource Center on Skidaway Island, Georgia provided us with a chance to use a large, untrained group as sensory panelists for our salted dried fish products. The group was a mixture of different ethnic groups, young and old, male and female. Most of them seemed to have a sincere interest in the testing and took it seriously. The testing area was a large, unused laboratory in which we had placed posters describing the general plan of our project.

The participants were directed to a triangle test in which two Norwegian pollock samples and one kingfish sample were compared side by side. Each sample consisted of a fillet cut into 5 x 7 cm sections, placed in a jar, and given a random, representative letter label. The panelists looked at the samples, then opened the jars in order to judge by smell. They were to put a mark by the letter, on their score sheets, corresponding to the odd sample and indicate whether they preferred the odd sample or the pair. They were also asked to do the preference test of different product forms of kingfish.

A nine point hedonic scale in our sensory tests was used with one as least desirable and nine as most desirable for appearance, color, flavor, aroma, and overall acceptability. Ratings for firmness and texture were based on a one-to-nine, soft-to-hard scale, with five as perfect. Score means were calculated and then ranked using Duncan's test at the 0.05 level.

RESULTS AND DISCUSSION

Production of Dried Fish

Figure 1 shows the change in moisture and salt content of the butterfly cut kingfish during the brining process. Results showed that two days of brining is necessary to get an equilibrium of salt and moisture content in the fish flesh.

Drying times were determined by recording the weight loss of fish during drying. Mechanical drying requires 48 hours for a 40% weight loss and 72 hours for a 43% weight loss (Figure 2). Sun drying takes five days (equal to 40 hours exposure under the sun) for a 40% weight loss in large fish (215 gm average whole weight) (Figure 3). The same size fish was used in both mechanical and sun drying. It takes two more days to get the same results for smaller fish (150 gm average whole weight). However, after nine days (equal to 72 hours) of drying under the sun, weight losses of both large and small fish are higher than those of fish dried mechanically for 72 hours. This is because sun drying allowed more time for water diffusion from the flesh to surface during the night. In this way more weight is lost in the same amount of drying time.

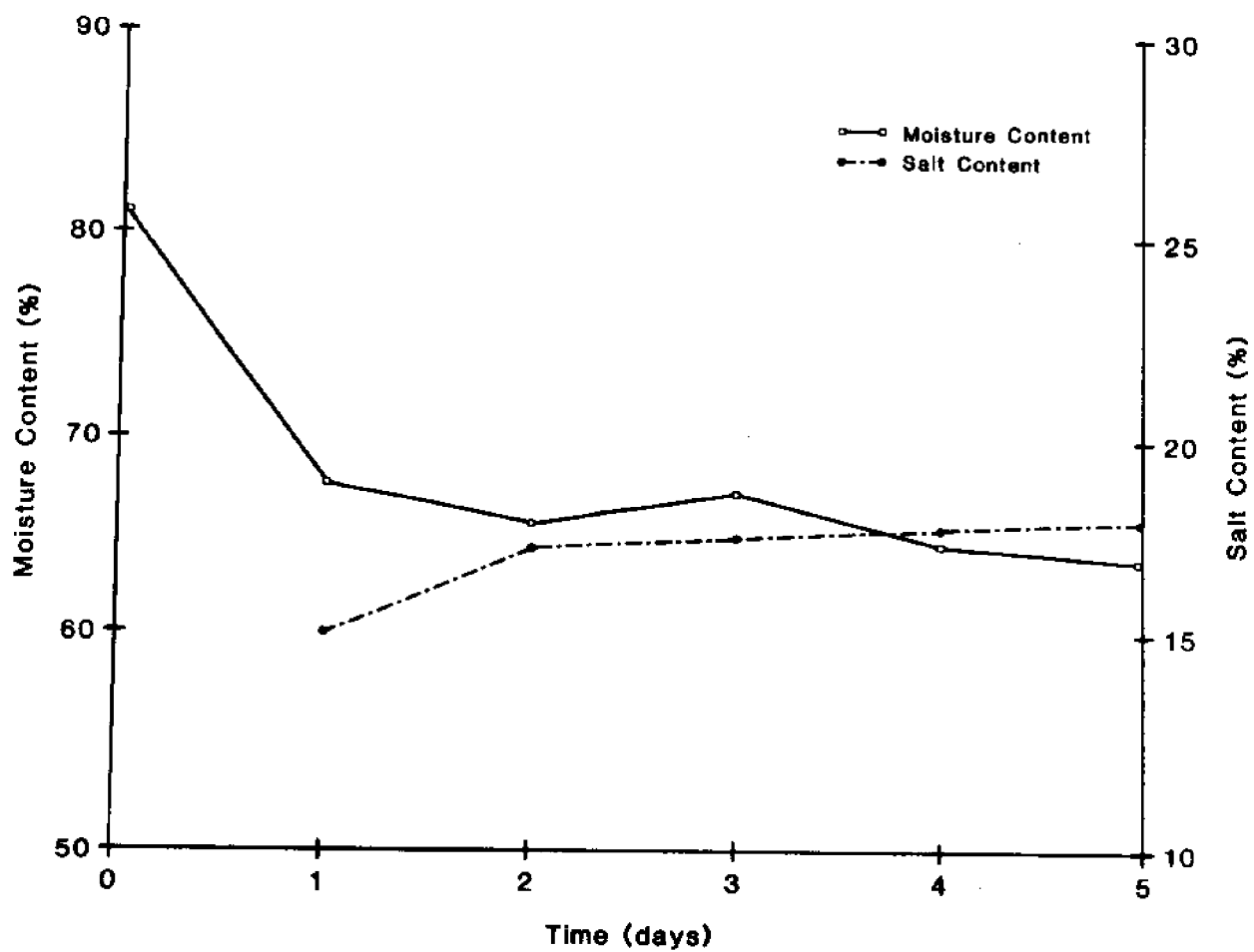


Figure 1. The salt and moisture content of kingfish during the brining process

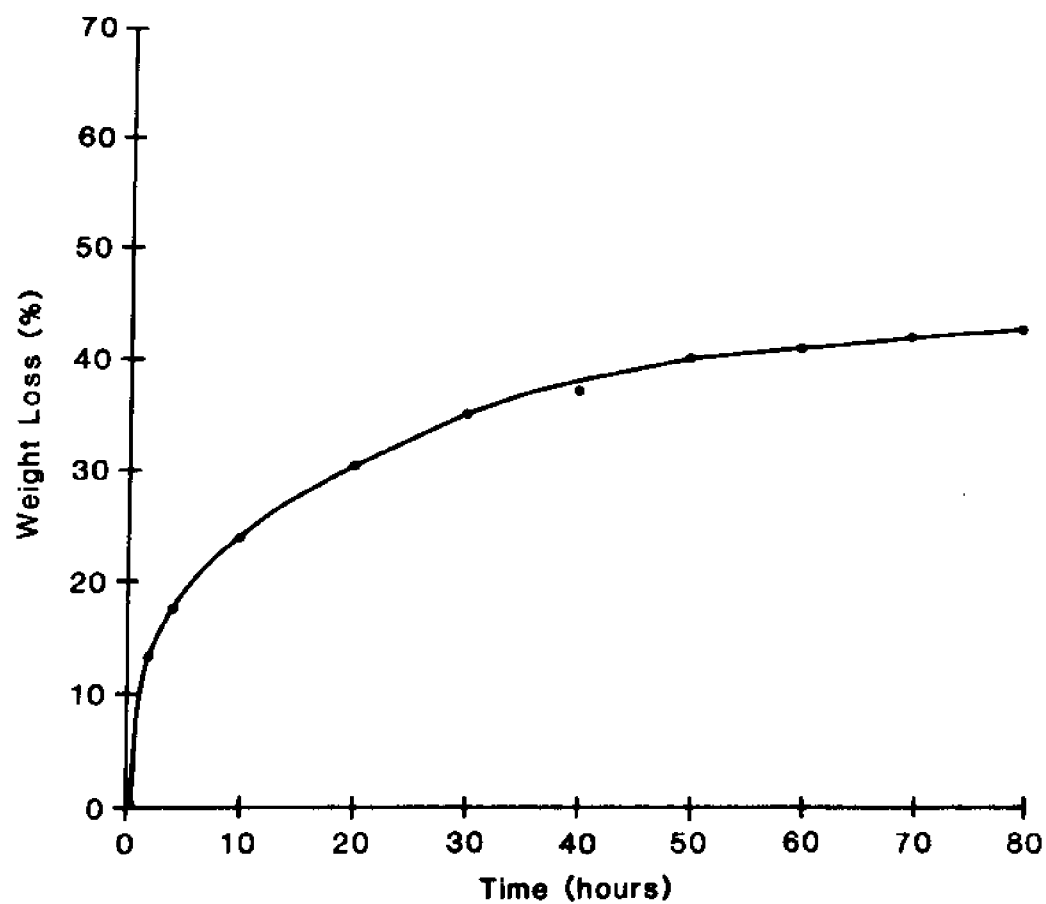


Figure 2. The drying curve of kingfish using the mechanical drying method

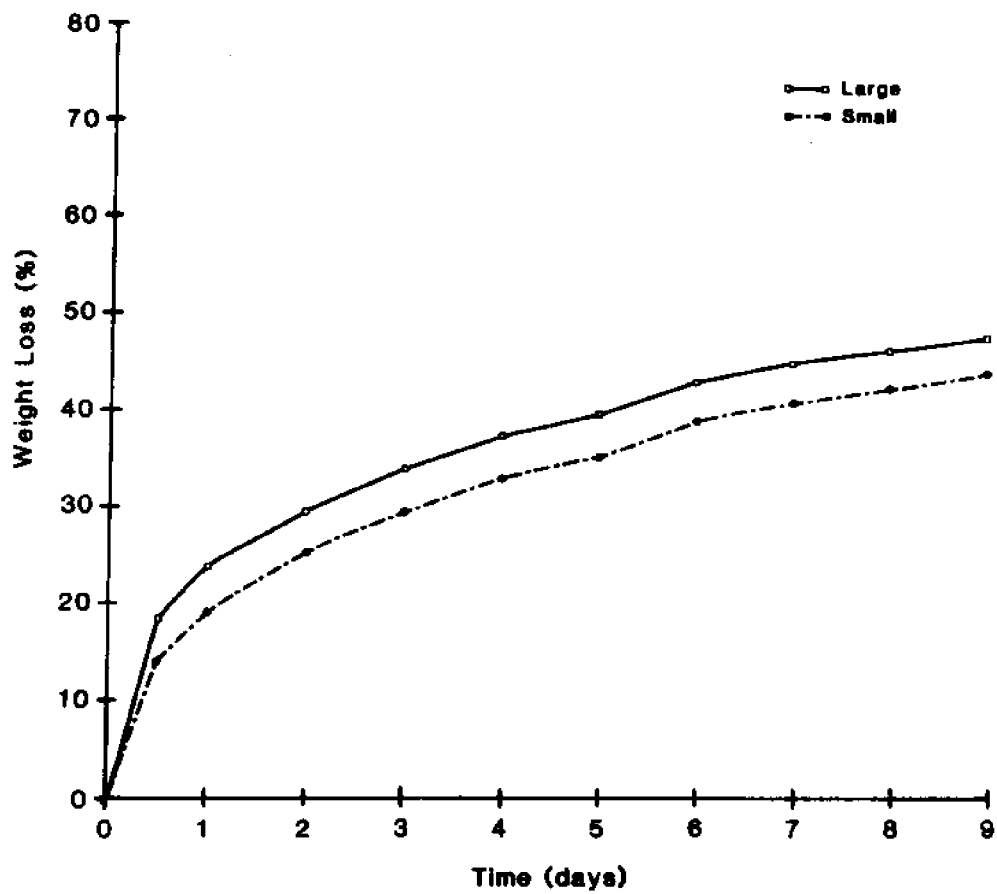


Figure 3. The drying curve of kingfish using the sun drying method

Chemical Analysis of Salted Dried Fish

Since mechanically and sun dried fish have similar moisture content, salt content, TBA and TMA values, only mechanically dried products were used in the study.

In order to match our products to traditional products, chemical compositions of salted dried pollock and kingfish products were analyzed. Moisture, salt, and fat contents, TBA and TMA values are listed in Table 1. Results show that Canadian pollock has a higher moisture content than that of Norwegian pollock and kingfish. However, kingfish has a much higher fat content. TMA values of pollock were much higher than that of kingfish as indicated by a strong fishy odor.

Compared to the salted dried fish made in Southeast Asian countries (Huang and Stephens, 1984), Norwegian pollock has a lower moisture content, while all three of the fish products in this study have higher salt contents.

Physical Characteristics of Test Products

Traditional commercial pollock and our product are physically quite different. Table 2 shows the measurement of size, weight, and rehydration ability of these products. Pollock is much larger than kingfish.

Organoleptic Analysis of Raw and Cooked Samples

Using the sensory evaluation for determining the acceptability by target market consumers is a very important step in the development of an exportable product. Although the salted dried kingfish is similar to the commercial pollock in a chemical respect, the organoleptic responses need to be matched.

Table 3 shows the acceptability test of different forms of kingfish evaluated by Venezuelan and American panels. Results of the Venezuelan panel show that butterfly cut samples with heads were very desirable followed by headless, butterfly cut samples. However, the American panelists noted very little difference in this test. Even though the score showed that headless, butterfly cut samples were rated higher, there was no significant difference.

All the samples were cut into 5 x 7 cm sections in order to eliminate any bias created by different sizes of the whole dried fish. The pollock from Norway rated very low with the Venezuelan panel with regard to color, aroma, and overall acceptability. The kingfish and Canadian pollock had close scores in each category except for color, where Canadian pollock was higher. American panelists rated Norwegian pollock slightly higher, but no significant difference was noted (Table 4).

Table 1. Chemical Analysis of Salted Dried Pollock and Kingfish

Product	Moisture content (%)	Salt ^a content (%)	Fat content (%)	TBA (μ m MA/100g)	TMA-A (mg/100g)
Canadian pollock	39.85	26.65	0.35	3.03	144.30
Norwegian pollock	29.05	22.70	0.74	4.05	16.91
Kingfish	36.58	25.82	9.53	4.29	2.43

^a Data on the salt contents of Canadian and Norwegian pollock are provided by NMFS Charleston laboratory

Table 2. Physical Characteristics and Rehydration Ability of Salted Dried Pollock and Kingfish

Product	Length (cm)	Width (cm)	Weight (cm)	Rehydration (%)
Canadian pollock	55 ^a	25	900	110.1
Norwegian pollock	45	20	550	125.1
Kingfish	20	10	100	135.8

^a Means of three samples except that of Canadian pollock which is a single sample

Table 3. Sensory Evaluation of Different Product Forms of Salted Dried Kingfish by Venezuelan and American Panels

Form ^a	Venezuelan Panel				Overall Acceptability
	Color	Aroma	Firmness	Appearance	
Z	9.00AB	8.43A	8.29A	9.00A	8.86A
V	5.86BC	5.86BC	6.57A	7.14AB	6.21B
W	5.07BC	6.36B	7.71A	6.71AB	5.86B
X	3.93C	5.07BC	7.00A	6.29B	4.71B
Y	6.29B	4.00C	7.00A	7.43AB	5.57B

Form	American Panel				Overall Acceptability
	Color	Aroma	Firmness	Appearance	
Z	5.17A	5.33A	7.50A	4.00A	5.00A
V	6.17A	6.00A	5.33A	6.83A	6.67A
W	4.67A	5.00A	7.17A	4.00A	3.67A
X	5.83A	4.67A	7.33A	5.83A	5.50A
Y	5.17A	5.50A	7.17A	6.33A	6.00A

^a Z: Butterfly cut
V: Headless, Butterfly cut
W: Dressed
X: Headless, Dressed
Y: Fillet

^b Means within the same column followed by the same letters are not different ($p > 0.05$)

Table 4. Sensory Evaluation of 5 x 7 cm Sections of Salted Dried Pollock and Kingfish by Venezuelan and American Panels

Product	Venezuelan Panel			Overall Acceptability
	Color	Aroma	Firmness	
Canadian pollock	8.71A ^a	8.86A	6.50A	8.14A
Norwegian pollock	4.00C	3.57B	5.00A	4.00B
Kingfish	6.71B	7.14A	6.43A	7.28A

Product	American Panel			Overall Acceptability
	Color	Aroma	Firmness	
Canadian pollock	4.67A	4.50A	5.67A	5.00A
Norwegian pollock	6.67A	6.67A	5.50A	6.50A
Kingfish	4.83A	5.33A	5.83A	5.17A

^a Means within the same column followed by the same letters are not different ($p>0.05$)

Cooked sample results (Table 5) show that the flavor and texture of both Canadian and Norwegian pollock was preferred by Venezuelans to kingfish. They expressed a desire for the slightly fishy taste and tougher texture.

For the comparison of whole headless, butterfly cut products, pollock had better scores than kingfish (Table 6). Venezuelan panelists said, although they like our products, they prefer larger and thicker fish.

One hundred and nine people participated in a triangle test conducted at the Marine Resource Center on Skidaway Island, Georgia. 48.6% of the participants correctly identified the kingfish as odd samples and 32.0% of these preferred the kingfish to the pollock. Results show that either the products are matched very well or participants have limited experience in distinguishing salted dried fish products. The preference test shows that they have a preference for dried fish without heads, which corresponds to the fresh fish forms consumed in this country.

CONCLUSION

Development of an alternative product for export needs to consider dietary habits and cultural traditions of the target market. Our study shows there is no problem in matching most chemical parameters between test samples and traditional samples. However, acceptability testing must be conducted and a quantitative level of acceptability needs to be determined. In this study, results suggest that fishy aroma and taste, indicated by high TMA values, are important to Venezuelan consumers. This project will continue with the testing of different species and target ethnic groups with the aim of finding the right combination. The success of product development depends on not only the quantitative determination of acceptability but also the market research.

ACKNOWLEDGEMENTS

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Table 5. Sensory Evaluation of Cooked Salted Dried Pollock and Kingfish by Venezuelan and American Panels

Product	Venezuelan Panel			Overall Acceptability
	Flavor	Texture	Appearance	
Canadian pollock	7.86B ^a	8.86A	7.57A	7.29A
Norwegian pollock	8.86A	8.14A	7.71A	7.71A
Kingfish	5.86C	5.43B	7.00A	5.14B

Product	American Panel			Overall Acceptability
	Flavor	Texture	Appearance	
Canadian pollock	7.12A	6.62A	7.50A	7.25A
Norwegian pollock	6.12A	5.75A	6.12A	5.75A
Kingfish	5.88A	5.50A	6.75A	5.88A

^a Means within the same column followed by the same letters are not different ($p>0.05$)

Table 6. Sensory Evaluation of Headless, Butterfly Cut Salted Dried Norwegian Pollock and Kingfish by the Venezuelan Panel

Product	Color	Aroma	Firmness	Appearance	Overall Acceptability
Pollock	8.00A ^a	7.86A	6.57A	8.43A	8.14A
Kingfish	4.43B	3.43B	4.43A	4.00B	3.86B

^a Means within the same column followed by the same letters are not different ($p>0.05$)

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SURVIVABILITY OF THE NEMATODE PARASITE, SULCASCARIS SULCATA,
IN THE CALICO SCALLOP AFTER NORMAL AND ALTERNATE PROCESSING TECHNIQUES

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INTRODUCTION

A rapid, recent growth in the calico scallop industry has attracted regulatory and industry concern for quality control in production. Prior to 1981 the recorded annual dockside production of processed scallop meat fluctuated below 3.0 million pounds. This production was primarily limited to a number of experienced firms in Florida and North Carolina which had evolved from sporadic developments initiated during the 1960's (1, 2, 3). Limited participation in the fishery had allowed some degree of 'self-regulation' for various quality attributes, including meat size (count per pound). In 1981 the regional production escalated to in excess of 14.6 million pounds. This increase was, in part, a result of additional participation in the fishery, increased fishing effort, and improved processing capability relative to shucking size. The calico scallop fishery had proven to be an attractive alternative for southern fishing vessels competing with increasing fuel costs to harvest a limited supply of shrimp. Likewise, the successful expansion of the fishery was a positive reflection on resource potential and market demand for this particular scallop. Estimated 1981 wholesale value of this fishery, calculated at a conservative value of 24 dollars per gallon, exceeded 43.8 million dollars. This value is impressive when realizing the majority of calico scallop production was concentrated at one location, Port Canaveral, Florida.

Consequences of this rapid growth were many newcomers, both to regulations and operations of calico scallop production, as well as more intense market competition. In some instances product quality suffered.

This rapid growth resulted in regulatory and industry concerns for quality control during production. One specific quality concern was the presence of parasites in the scallop meats. In the Fall of 1981, the U.S. Food and Drug Administration (FDA) recommended a temporary action level of 20 percent parasites permissible in calico scallops (Basis: one percent equals one parasite per one scallop meat per one hundred scallop meats). Subsequent inspections have alarmed the industry, altered fishing activity, stifled some wholesale transactions and, in at least one case, forced the destruction of 13,000 pounds of processed meats with a 1982 wholesale value in excess of 50 thousand dollars.

The occurrence of parasites in calico scallops is not a new phenomenon. The primary parasite in question is the nematode, Sulcascaaris sulcata. Presence of this parasite and similar forms in scallops have been documented since 1930 (4) and described from the commercial region for calico scallops in natural concentrations exceeding 38 percent infestation (5,6). Occurrence of this parasite as influenced by geographic location, season and scallop size is currently under investigation (6), and Otwell and Walker (7) have reported consumer perception of S. sulcata in calico scallops is extremely low. The present study addresses the survivability of the parasite as affected not only by present processing techniques but by alternate processing techniques. Also addresssed is the potential for the parasite to survive human digestion and body temperature.

METHODS

Percent occurrence and percent survival within occurrence (survivability) was monitored for parasitized meats (at least one externally visible cyst per adductor muscle) separated from the total meats sampled from the predetermined processing points (Figure 1). Parasites were teased from cysts with forceps and needles. Parasites were considered alive if they responded to slight agitation after 1 hour in Earl's solution. The survival response was similar to fluids drained (seepage) from the shucked meats.

Attempts to decrease the percent occurrence included additional passes across the eviscerater, hand-sorting, freshwater soaks (1.7°C, 35°F) and direct heat treatment. Attempts to decrease percent survival included iced storage, refrigeration (1.7°C, 35°F), super-chill (-2.2°C, 28°F), frozen storage (-17.8° and -34°C, 0° and -30°F), freshwater soaks (1.7°C, 35°F), exposure (12 hours) to 0.25 and 0.50% bisulfite solutions, sonication, and heat treatments (steam and micro-wave).

RESULTS AND DISCUSSION

The encysted parasite, Sulcascaaris sulcata, visible on the surface of the raw meats, was present in all harvests throughout the duration of the study. Percent surface occurrence ranged from 14% to 40%.

Figure 1

Illustration of processing operations and processing points used for sampling throughout the study.

Processing (Sampling) Points:

1. Shellstock from dockside
2. Steam shucked meats and water
3. Eviscerated meats
4. Meats and water from chill tank



The occurrence of parasites was almost always in excess of FDA's temporary 20% action level for adulterated product. Attempts to avoid harvesting scallops with high levels of infestation proved futile and impractical. Occurrence could not be predicted by fishing depth, bottom type, location, scallop size, or season. Fishing efforts substantiate previous reports on futility in trying to avoid occurrence. Likewise, attempts to remove the infested scallops by hand slowed the culling procedure. Hand culling is totally impractical realizing meat counts can range in excess of 250 meats per pound, parasites are difficult to detect, internal parasites are not visible and the culling rate must match the production rate of the mechanized shucking/evisceration equipment. A slow culling rate causes product accumulation and backups which expose the meats to potential contamination and thermal abuse. Further sorting prior to packaging was also impractical and enhanced thermal and microbial abuse.

Additional processing on the evisceration apparatus was investigated in an effort to remove parasites while processing. The thought was to use the abrasive action of the rubber coated evisceration rollers to grind the parasites from the surface. After three runs for the same scallop meats (10 gallons) passed across the same eviscerator, the viable parasite counts still remained as initially recorded. The additional process could not remove parasites internally viable within the individual scallop meats. Scallop meats with an initial meat count of 136 ± 6 ($n = 250$) increased in counts to 144 ± 7 and 155 ± 6 after a second and third pass over the eviscerating table, respectively. Thus, extra evisceration caused 5.9% and 14.0% increases in meat count, and softened and fragmented the surface of the extra processed meats. The results of extra evisceration were lower yields, inferior product quality, and persistent parasites. Thus, no alternate methods for processing seem plausible or practical for removing the parasites to decrease percent occurrence without detrimental influences on product quality.

Recognizing calico scallop parasite infestations often exceed 20% and processing cannot decrease percent occurrence, attempts focused on killing the larval nematodes to minimize aesthetic problems. An initial study monitored survival of the parasites during typical processing. After the various processing stages, at least 20 individual larval parasites were dissected and placed in either Earl's solution or saline solution at room temperature (20°C). Parasites were considered to be displaying a live response if they moved while soaking and being agitated within 1 hour in the solution. The survival of the larval parasites was determined using scallop meats of shellstock immediately upon ship arrival at dockside, after steam shucking, after evisceration by rollers, immediately after cooling to 5°C (40°F), and after 1 day storage at 5°C. Approximately 45% of the external parasites present were able to survive complete processing and refrigerated storage of one day (Table 1). Thus, the calculated percent live parasite occurrence for this one harvest exceeded 17%. Further sampling from additional vessels and during October through August indicated the percent survivability for parasites present ranged from 40% to 60%. Thus, the possible percent live parasite occurrence for processed meats during this study was calculated to range from 5.6% to 24% (% occurrence times range in % survivability).

Table 1. Occurrence and survival of larval parasites, Sulcascaris sulcata encysted on raw calico scallop meats during harvest and processing from one vessel.

Stage of Processing	% Total Occurrence* per 100 meats	% Survivability** per 20 parasites	% Live Parasite*** Occurrence
Shellstock	38	60	22.8
Steam-Shucked	36	40	14.4
Eviscerated	37	25	9.3
Cooled (5°C) (immediate)	39	45	17.6
Cooled (5°C) (one day)	38	45	17.1

* % Total Occurrence accounts for all meats with at least one visible, external cyst.

** % Survivability accounts for all parasite nematodes displaying an alive response. Sample size included 20 parasitized meats.

*** % Live Parasite Occurrence = % Occurrence x % Survivability.

Additional cooling and freezing during the storage of processed meats could decrease the parasite survivability. Refrigerated storage from 1.7°C (35°F) to 0°C (32°F) depressed survivability but the results varied depending on the initial condition of the scallops and parasites (Table 2). Variability in survival was evident for the results for separate harvests stored for 45, 70 and 168 hours. In trials, 20% of encysted parasites exposed to 0°C (32°F) for 70 hours survived. Thus, recognizing fresh calico scallops can be distributed to markets and consumers within less than 72 hours after processing, parasite survival is possible on raw refrigerated meats. Although prolonged super chilling (-1.0°C, 30.2°F) provided more kill than typical refrigeration temperatures, frozen storage (-3° or -30°C) provides the only complete kill of all parasites on the meats.

Parasite survivability was also depressed by elevated temperatures in excess of 30°C (86°F) (Table 3). These results were determined for live parasites dissected from the meats and subjected to temperatures elevated above normal processing conditions. Temperatures of 35°C (95°F) or above provided an almost immediate, total kill. Thus, it is doubtful that parasites, even if eaten as part of uncooked scallop meats, can survive a human body temperature of 98.6°F (37.5°C). Although this is a promising result, normal heating procedures (at least for short durations) which may allow the internal meat temperature to reach 95°F thereby killing all the nematodes, may heat the exterior of the meats above 100°F (43°C) thus initiating cook and affecting meat quality.

Although it is clear that the nematodes cannot survive human body temperature, other experiments were performed to determine the effects of mammalian digestive juices upon the survivability of the nematodes. Nematodes were dissected from scallop meats and force-fed to white mice by holding the mouths open and forcing the living, whole parasite down the esophagus into the stomach. The mice were then sacrificed at various time intervals, dissected, and the presence of the parasites determined in the stomachs. Parasites were also directly exposed to gastric juices extracted from the stomachs of mice. The results of the digestive experiments are shown in Table 4. In no instance was it possible to find the presence of any nematodes. After only 15 minutes in the stomach, the parasites were apparently digested. In the extracted gastric juices parasites began to dissolve in only 5 minutes and within 15 minutes discernible parasites could not be detected. Thus, there appears to be little possibility that larval Sulcascaris sulcata poses a threat to human health.

Further attempts to kill parasites with heat included an innovative steam tunnel installed after evisceration and prior to the chill tank. The tunnel specifications were designed by a participating scallop firm requesting equipment confidentiality. The tunnel was operating at an internal temperature of 49°C (120°F). Eviscerated scallops with an external temperature of 26.6°C (80°F) entered the tunnel for a residence (exposure) time of 10 to 20 seconds. Although the steam tunnel imparted additional parasite mortality (Table 5), the steam treated meats had a noticeable softer, fragmented texture which was detrimental to final production quality. Subsequent storage at 1.7°C (35°F) indicated the

steam treated meats spoiled more rapidly than non-steam treated meats. The steam tunnel was declared partially effective but detrimental to meat quality.

Further heat applications were performed using a conventional microwave oven in an attempt to rapidly elevate both the external and internal meat temperature sufficiently to destroy the nematodes but not significantly affect meat quality. In these experiments meats containing at least one parasite were exposed to high and low settings of the microwave oven for various periods of time after which the parasites were dissected and their survivability assessed. As in the previous experiments, external and internal meat temperature had to exceed 30°C (86°F) in order to significantly affect the parasite survivability (Table 6). Length of exposure as well as degree of exposure also affected survivability with a low microwave setting for 60 seconds or a high setting for 15 seconds necessary to kill greater than 90% of the parasites. Ice treatment following microwave application was deemed necessary for good manufacturing practice and to prevent further loss of meat quality, but the cold temperature stopped residual heating and enhanced parasite survival (Table 7). Thus, the microwave technique appears to offer some promise. Meat quality did not appear to be affected by the high setting/short time microwave treatment. If the technique were applied to the commercial operation, careful monitoring would have to be employed to insure that meat temperatures reached 40°C for at least 60 seconds or 45°C for 15 seconds. Continuous treatment of microwave units for commercial in-line application are available and may be applicable to continuous processing schedules.

Scallop meats were also exposed to a series of "soaks" to determine if the parasites could be killed by disrupting their osmotic balance. Scallop meats containing surface parasites were placed in two concentrations of sodium bisulfite for 12 hrs after which time the survivability of the nematodes was determined. Many of the parasites appeared to tolerate concentrations ranging from 0% (fresh water) to 0.5% bisulfite (Table 8). In fact, the parasites from scallops in the higher concentration appeared to be stimulated ("hatched" and crawling on the meats). The bisulfite soaked meats retained their color and odor, but they were swollen and soft. Survivability and detrimental product quality precluded continued use of soaks to kill parasites. Likewise, the prevailing regulatory concerns for use of sulfiting agents in foods would probably eliminate such treatments.

Finally, one of the newer techniques in food processing is sonication. A Bronson E-module ultrasonic generator was utilized to determine the effects of sonication on parasite survival. The generator was attached to a 6 inch circular metal water jacket surrounding a central plastic tube (one inch diameter). The plastic tube could be filled with the material to receive sonication and the sonication was transmitted from the generator through the water surrounding the tube. Water in the jacket was circulated through refrigeration to control temperature. The sonication destroyed all dissected parasites suspended in the plastic tube of water, but the parasites within cysts on the scallop meat survived the same application (Table 9). Survival precluded continued use of sonication.

Table 2. Effects of additional cooling and freezing on survivability of parasites, S. sulcata on raw calico scallop meats.

Storage Temp. °C	Storage Temp. °F	Exposure* (hours)	Number Meats with Parasites	No. Parasite Surviving	Percent Survivability
1.7	35.1	45	37	1	3
1.7	35.1	70	20	13	65
1.7	35.1	68	31	2	7
1.7	33.8	12	30	17	57
0**	32.0	45	39	1	3
0	32.0	70	15	3	20
0	32.0	168	38	0	0
-1.0***	30.2	13	30	10	33
-1.0	30.2	45	34	0	0
-1.0	30.2	70	19	2	11
-3.0	26.0	45	29	0	0
-30.0	-22.0	70	21	0	0

* Exposure trials for 45, 70 and 168 hours include two separate harvests.

** Iced storage.

*** Super chilled product, remained unfrozen.

Table 3. Survivability of live parasites (20) dissected from calico scallop meats, suspended in Earl's solution, then exposed to temperatures elevated by water bath treatment.

Temperature of Bath		No. Alive After 1 hr. Exposure	Percent Survivability
$^{\circ}\text{C}$	$^{\circ}\text{F}$		
10	50	20	100
15	59	20	100
20	68	15	75
25	77	12	60
30	86	5	25
35	95	0	0
40	104	0	0

Table 4. Effects of mouse ingestion and digestive juices on survivability of nematodes, S. sulcata on calico scallops.

Number of Mice	No. Nematodes Fed/Mouse	"Digestion" Time (min.)	No. Nematodes Recorded
10	20	60	0
10	20	30	0
10	20	15	0
10*	20	15	0

* extracted digestive juices

Table 5. Survivability of nematodes following heat treatment in a steam tunnel 49°C (120°F). Averages represent results from three separate vessels identified as A-C. All vessels landed the same day in December.

Vessel	Stage of Processing	% Total Occurrence per 100 meats	No. Parasites Alive	Percent Survivability
A	eviscerated* steam treated	22	9	41
		17	3	18
B	eviscerated steam treated	12	2	17
		13	2	15
C	eviscerated steam treated	18	7	39
		17	4	24
Average	eviscerated steam treated	17	6	35
		15	3	20

* Separate samples (100 meats) were taken immediately after evisceration and after steam tunnel treatment.

Table 6. Survivability of parasites, S. sulcata after microwave heat treatments.
All scallops treated came from the same original harvest through typical processing. Initial infestation level was 27%.

Energy Setting/Time (sec.)	Resulting Meat Temp. °C	No. Parasitized Meats Treated	Percent Survivability
Control (no treatment; iced)	(O)* (I)**		
Low/30	29	10	60
Low/30	29	10	40
Low/30	30	10	50
Low/60	45	10	0
Low/60	45-50	10	0
Low/60	40-50	10	10
High/15	41.5	5	20

* (O) = outside meat temperature.

** (I) = internal meat temperature.

Table 7. Survivability of parasites, *S. sulcata* after microwave treatments and subsequent ice treatment. All scallops came from the same original harvest through typical processing. Initial infestation was 18%.

Energy Setting/Time (sec.)	Resulting Meat Temp.	Ice Treatment		No Ice Treatment	
		No.* P-meats	Surviv.** (%)	No. P-meats	Surviv. (%)
	(°C)				
High/15	45	11	0	12	0
		12	0	13	0
		9	11	12	0
Low/60	43	13	7	8	0
		10	10	8	0
		8	0	13	0

* No. P-meats - number of parasitized meats treated.

** Surviv. - % survivability.

Table 8. The effect of sodium bisulfite "soaking" on the survivability of nematodes.

Bisulfite Concentration (%)	No. Parasitized Meats Treated	Percent Survivability
0	20	40
.25	20	40
.50	20	40

Table 9. The effects of sonication on survival of parasites, S. sulcata from meats of calico scallops.

Vibration Time	Water Temp. (C)		No. Parasitized Meats Treated	Survivability %
	initial	final		
60 (meat)	24	27	5	100
120 (meat)	24	28	3	100
60 (dissected parasites)	24	27	3	0

Thus, it appears that physical removal of the parasite is not possible and destruction of the parasite is difficult although it may be possible with alterations in the present processing and handling techniques. However, even without these changes to kill the parasite, the evidence from this study further substantiates the fact that the nematodes are killed by human body temperatures and are easily dissolved by digestive juices.

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EFFECTS OF HOLDING TEMPERATURE ON BODY CONDITION OF
STARVED ADULT NOBLE CRAYFISH, ASTACUS ASTACUS LINNE
(DECAPODA, ASTACIDAE), FROM CENTRAL FINLAND

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INTRODUCTION

Freshwater crayfishes are important fisheries products in parts of North America, Europe, and Australia (5). The major product form is the intact animal, boiled or steamed alive and served immediately or frozen for later use. Live crayfish are highly perishable and must be treated carefully. They may be held in live boxes or in waterless cold but humid air. Submerged Astacus astacus will persist for 6 weeks at 4°C with little change in internal condition (7). The effective holding period for Procambarus spp. (P. a. acutus and P. clarkii) is 5-7 days in a humid atmosphere at 4°C (6). A. astacus held under such conditions have a weight loss of about 6%. Fortunately this loss is not critical in Europe because such crayfish are sold on a per piece basis but similar weight losses can be significant where crayfish are sold on a weight basis as in the case in the USA.

Abundant crayfish supplies have led to the development of a crayfish processing industry in the southern USA (Louisiana) where the abdominal muscle, or "tail meat" is recovered, normally by hand peelers (6). Meat yield is an important consideration whether the crayfish are to be sold intact or peeled for tail meat. Europeans often include chelae muscles in determining crayfish meat yield as crayfish are very scarce and have high individual values (2, 8, 11, 13). However, the U. S. processing industry removes tail meat only (2, 12).

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It is well known that meat and edible organ (hepatopancreas and gonad) yields are functions of sex, reproductive state, and molt stage in crayfish but few data are available for any species. Dabrowski et al. (2), Kossakowski (8), Lindqvist and Louekari (11), and Rhodes and Holdich (13) provide some data for various European species including A. astacus, Astacus leptodactylus, Austropotamobius pallipes, and Orconectes limosus. A few data are available for Procambarus spp. (P. a. acutus and P. clarkii) from the USA (6). In general tail meat yield is about 15% of total body weight. Chelae meat yield is 3-5% as is hepatopancreas yield. Ovary yield rarely exceeds 3%.

We initiated this study to obtain data on the effects of holding temperature on submerged, starved A. astacus over a short holding period totaling 2.5 weeks. Recovery of abdominal muscle and edible organs provided additional information on yields and composition of these materials for this species.

MATERIALS AND METHODS

Sexually mature, mostly intermolt A. astacus were collected with baited traps in mid-July 1984 in Valkealampi Pond located near Kuopio in central Finland. Ambient water temperatures were around 20°C. Size was approximately 44 mm carapace length and 18 g wet body weight. Initially all crayfish were held submerged at 4°C for 10 days. At that time, a number was transferred to holding tanks at 20°C. After an additional 8 days, 12 males and 12 females were removed from holding containers at the two temperatures and frozen at -60°C. Crayfish were not fed nor was there any cannibalism during the study period. The crayfish were subsequently thawed and dissected.

Abdominal muscles, hepatopancreases, and gonads (ovaries only) were removed and weighed to the nearest 0.0001 g. Abdominal muscle was then thoroughly rinsed with fresh water and placed on absorbent paper for about 30 minutes to remove excess moisture and reweighed. Moisture content of abdominal muscle and hepatopancreas was determined by drying samples overnight at 80°C. Muscle and hepatopancreas samples were subsequently pooled and analyzed for crude protein (muscle only) and lipid. Protein was determined using the Kjeldahl method for protein in cereals and cereal products, Kjeltac System I or II and Hg catalyst. The conversion formula was:

$$\% \text{ Protein} = \frac{(A-B) \times N \times 14.007 \times f \times 100}{\text{mg of sample}}$$

where:

A = ml of acid for titrating the sample
B = ml of acid for titrating a blank sample
N = Normality of acid used for titration
f = factor 6.25
100 = conversion to %

Lipid was measured colorimetrically according to the method of Frings and Dunn (3). Intermolt and premolt (7 of 48 crayfish) were separated in all analyses. One way analysis of variance was used to compare means where individual data were collected. Chi-square one-sample test for goodness of fit was used to compare composite protein and lipid samples. A probability value of $P < 0.05$ was considered to represent a statistically significant difference.

RESULTS AND DISCUSSION

The principal store of organic reserves in decapod crustaceans in the hepatopancreas (1, 15). It is more sensitive to starvation than abdominal muscle. Lipid is the principal energy source for crayfishes (1, 14).

We found that both male and female intermolt A. astacus held at 4°C had significantly larger hepatopancreases than those transferred to 20°C (Table 1). There were no significant differences within sexes in hepatopancreas moisture but significant differences between sexes in favor of females. This trend held for lipid content also (Table 2) where only chi-square data comparisons could be made. We have no data on the status of the crayfish when they were captured and limited data when the 20°C group was transferred to warm water; however, hepatopancreas masses were 5.7% (SD = 0.5, n = 17) and 7.2% (SD = 0.66, n = 23) in comparable males and females, respectively, at the time of transfer suggesting reduced metabolism and little change in test animals retained at 4°C during the 8 day test period. This is in agreement with Huner et al. (7) who noted little change in body condition of starved A. astacus held at 4°C for longer periods.

Mobilization of organic reserves from the hepatopancreas to the ovaries is apparent in females held at 20°C. The significant increase in ovarian mass matches the significant decrease in hepatopancreas mass when compared to crayfish held at 4°C (Table 1). Ovary mass of females at the time of transfer to 20°C was 2.1% (SD = 0.46, n = 23) and was comparable to that of the crayfish retained at 4°C, 1.8% (SD = 0.4, n = 11). This increase in ovary mass corresponds to observations made by Lahti and Lindqvist (11) who had previously noted an increase of similar magnitude in wild stocks in area lakes and rivers at the same time. In contrast, male reproductive organs, testes and vas deferens, accounted for less than 0.2% of body weight and no apparent changes in sizes and appearance were noted.

Premolt crayfish had larger hepatopancreases with less moisture and greater lipid stores (Tables 1 and 2) than intermolt crayfish regardless of treatment. This is consistent with storage of nutrients in that organ prior to the molt (1). Larger abdominal muscle masses in premolt crayfish might suggest that such crayfish would be more desirable to consumers. However, premolt crayfish are very vulnerable and difficult to sustain using conventional waterless shipping and storage technology. Thus, it is doubtful that such crayfish will become widely available or important.

Abdominal muscle data are not consistent with hepatopancreas data. There were no differences between washed muscle in males but 20°C females had significantly larger muscles than 4°C females. Unwashed muscle sizes of males and females at the beginning of the 8 day holding period were 13.9% (SD = 1.24, n = 17) and 16.4% (SD = 1.47, n = 23), respectively. These were generally comparable to 4°C crayfish after 8 days but were lower than the values for the 20°C crayfish (Table 1). Reasons for this contradiction are not readily apparent but increased muscle moisture (see below) may partly explain this condition.

Both male and female crayfish had higher muscle protein and lipid levels at 20°C (Table 2). Chi-square comparison of these data, however, show no significant differences between treatments. One would expect that 4°C crayfish would have a lower metabolism than those at 20°C. This was much more apparent in hepatopancreas data but both sexes did have lower muscle moisture levels at 4°C that was either significantly lower (males) or approached a significantly lower value (females, P = 0.13). Further, muscle moisture values of females were consistently and significantly lower than males regardless of temperature denoting lower metabolism in females. The general absence of identifiable changes in muscle masses agrees with other studies that show minor changes in abdominal muscles in starved crayfishes (4, 14) and lobsters (15) over relatively brief periods.

Commercial interests are concerned with muscle and organ yields as well as nutritional quality. Muscle yields were substantially decreased by washing and draining. Wash loss ranged from 15-20% of the original weight for the frozen and thawed product. This is of little importance if intact crayfish are consumed but can clearly impact profits in a processing industry. Although most crayfish muscle is processed by hand peeling of parboiled crayfish (6, 12), the only functional peeling machine peels crayfish abdomens that have been frozen and thawed rather than parboiled ones (6). Such muscle, whether parboiled or "fresh", must be washed if it is to be frozen as hepatopancreatic material will cling to it and become denatured grossly affecting product quality. Thus, wash loss will adversely affect yields and profits but cannot, at this time, be avoided.

Our yield data are comparable to that reported elsewhere for various crayfish species including A. astacus (2, 6, 8, 11, 13). Further, nutrient content is also consistent with those reports and others (1, 4, 14). We found that mature female A. astacus consistently yielded more usable material, over 20%, than males. We did not measure chelae muscle in this study but earlier noted that males had larger chelae and more muscle in them (unpublished data). This is a well known crayfish phenomenon (6, 8, 10, 11, 13). However, females would still have had a decided advantage over males when total quantity of edible tissue is considered. The commercial importance of this situation is questionable as there is marked consumer preference for large males with their inflated chelae (6, 10, 11, 13).

In conclusion, A. astacus were held at 4° and 20°C for 8 days following confinement at 4°C for 10 days in mid summer. At an ambient temperature of 20°C, starved crayfish exhibited a reduction in hepatopancreas size and quality but there was little change in abdominal muscle. Metabolism was clearly reduced at 4°C. Females yielded more edible abdominal muscle and organ material than males regardless of holding temperature. The advisability of holding live crayfish submerged at low temperatures prior to sale will depend on cost factors that were not considered in this study but quality would certainly be improved.

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Table 1. Muscle and yield data for starved Astacus astacus held submerged initially for 10 days at 4°C and transferred to 20°C or retained at 4°C for an additional 8 days.

Treatment	% Recovery of Abdominal Muscle		% Recovery of Hepatopancreas Gonad	% Recovery of Hepatopancreas	% Moisture
	Unwashed	Washed			
<u>Male 20°C</u>					
Intermolt (n = 9)	14.6±0.94	12.1±2.86	4.5±0.80	—	84.3±0.88 84.2±2.27
Premolt (n = 3)	18.2±1.97	15.5±2.01	6.1±0.50	—	80.9±0.74 74.9±3.66
<u>Male 4°C</u>					
Intermolt (n = 10)	15.0±0.92	12.0±1.01	6.0±0.28	—	83.6±0.60 83.9±1.68
Premolt (n = 2)	17.9±1.34	14.7±2.12	7.1±0.85	—	81.9±0.85 76.5±0.78
<u>Female 20°C</u>					
Intermolt (n = 11)	18.6±0.95	15.9±0.66	5.8±0.70	2.7±0.60	83.3±1.08 76.9±7.09
Premolt (n = 1)	20.4	17.4	6.7	0.8	80.4 67.1
<u>Female 4°C</u>					
Intermolt (n = 11)	17.2±1.44	14.1±1.29	7.0±0.87	1.80±0.40	82.6±2.13 78.8±4.8
Premolt (n = 1)	20.2	16.2	7.2	0.6	80.7 73.7

*Values are means ± one standard deviation.

Table 2. Protein and lipid values for abdominal muscle and hepatopancreas of starved Astacus astacus held submerged initially for 10 days at 4°C and transferred to 20°C or retained at 4°C for an additional 8 days.

Treatment	Abdominal Muscle		Hepatopancreas	
	<u>Protein (% of dry weight)</u>	<u>Lipid (mg/g of dry weight)</u>	<u>Protein (% of dry weight)</u>	<u>Lipid (mg/g dry weight)</u>
<u>Male 20°C Intermolt</u>	84.9	23.9		246
<u>Male 4°C Intermolt</u>	81.5	21.2		325
<u>Female 20°C Intermolt</u>	80.9	21.8		424
<u>Female 4°C Intermolt</u>	80.1	20.3		372
<u>Male/Female 4 & 20°C Premolt</u>	82.4	22.2		461

SENSORY AND INSTRUMENTAL EVALUATION OF DIFFERENCES
BETWEEN RED SWAMP AND WHITE RIVER CRAWFISH MEAT

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INTRODUCTION

Crawfish culture and processing are becoming increasingly important in the United States. In 1984, Louisiana harvested more than 75 million pounds of crawfish from natural areas, such as the Atchafalaya Basin, and from over 100,000 acres of ponds. Red swamp crawfish (Procambarus clarkii) and white river crawfish (Procambarus acutus acutus) are the two species of commercial importance in Louisiana and surrounding states.

Both species are harvested simultaneously in varying proportions. Commercial catches delivered to processing plants are sold live or further processed. According to Lovell (3), neither species has a commercial advantage over the other. In some cases, traditional preferences have been expressed favoring red crawfish. In whole live animals, different species are easily recognized, thus species composition may influence customers' purchases of live crawfish. Processors have also indicated a difference in appearance of processed meat obtained from the two species, and often find it necessary to blend crawfish from different areas as they process if they are receiving some sacks from an area where white crawfish predominate.

Differences in crawfish meat processed from red and white crawfish have not been determined. The purpose of this study was to evaluate some of these differences using sensory and instrumental techniques.

METHODS

Sample Preparation

On three occasions, washed live red and white crawfish were cooked separately in boiling water using simulated commercial procedures. Samples for instrumental color and texture analysis were placed in boiling water and cooked until a return to boil was reached. This required seven minutes. As crawfish were peeled, hepatopancreas or "fat" samples representative of the color range present in each species were set aside for Hunterlab Colorimeter analysis. Meat samples for color analysis were washed of "fat" and blended 1:1 with water. Meat samples for Instron texture analysis were also washed of "fat".

Red and white crawfish for sensory evaluation were cooked 13 minutes, which was six minutes after a return to boil was reached. After peeling, "fat" was washed from half of the samples. Tails were cut in 3 or 4 pieces, and those from like groups were mixed to insure representative samples for panelists.

Sample Analysis

Color of "fat" and meat from the two species was measured with a Hunterlab Tristimulus Colorimeter, Model D25M-9, using the "Lab" scale. Measurements were made on a 2-inch circular area of macerated "fat" or meat paste, using methods described by Himelbloom (1). Color of fresh meat and "fat" was measured. Color of "fat" was also measured after 20 hours of storage at 3°C.

Instrumental evaluation of meat texture was done with an Instron Universal Testing Machine (Model 1122), using the Kramer food testing attachment. Settings of 100 full scale load and 500 crosshead speed were used. Crawfish meat was brought to room temperature prior to analysis. Each sample was weighed and the number of tails noted. Tails were placed randomly in the cell, and samples were run in a randomized block design. Peak force values were used to determine the kg/g shear force for each sample.

Sensory evaluation was done with a nine member panel using a series of triangle tests, as described by Larmond (2). Samples evaluated consisted of red or white crawfish meat, with or without "fat". During each of three sessions, panelists evaluated two triangles with "fat" and two without, the first of each done under red light, the second set under white light.

Statistical analysis of Instron and Hunterlab data was done by analysis of variance, using a randomized block design with a factorial arrangement, as described by Snedecor and Cochran (4). Sensory panel data was analyzed by tables for rapid analysis of triangle test data (2).

RESULTS

Hunter values showed significant differences in color between "fat" and meat samples taken from red swamp and white river crawfish. "L" values designate light-dark differences, with higher values indicating lighter coloration. There were highly significant differences ($P < 0.0005$) in "L" values of "fat" between batches, and of meat between species. Mean "L" values of "fat" for different batches were 44.38, 42.79 and 38.78. Mean "L" values for red and white crawfish meat were 41.33 and 42.63 respectively.

Hunter "a" values indicate red-green differences, with green being indicated by negative numbers. The lower the number, the more green hue present; the higher the number, the more red present. There were highly significant differences ($P < 0.0005$) in "a" values of "fat" between batches and species. Mean "a" values for different batches were 4.29, 3.19 and 5.65. Mean "a" values for red and white crawfish "fat" were 7.17 and 1.58, respectively. Although a significant difference was not found in color change of the "fat" over a 20 hour period, it was of interest to note that "a" values of red crawfish "fat" were 7.21 and 7.14 at time zero and 24 hours, while white crawfish fat "a" values were 2.22 and 0.96, respectively. The increase in green color of the later was very obvious to the observer. Highly significant differences ($P < 0.0005$) were also noted in "a" values of meat from the two species, with values of 64.70 and 67.62 for red and white, respectively.

being indicated by negative numbers. Again, lower numbers indicate more blue present, and higher numbers indicate more yellow. Significant differences ($P < 0.05$) between batch and species were noted in "b" values of "fat". Mean "b" values for "fat" from different batches were 20.4, 20.2 and 18.5. Mean "b" values of "fat" from red and white crawfish were 20.25 and 18.94. Significant differences ($P < 0.025$) were also observed in a species by hour effect. Mean "b" values of "fat" from red crawfish were 20.25, both at time zero and after 20 hours of storage. Similar values for "fat" from white crawfish were 19.40 and 18.47, respectively.

Instron Kramer shear values showed no significant difference in texture between the two species. White crawfish had slightly higher values of 1.60 kg/g than did red crawfish, with 1.56 kg/g. White and red crawfish tails averaged 3.99 and 4.32 g each, respectively.

Sensory evaluation showed no overall significant difference ($P > 0.05$) between the two species. Only in two sets of tests out of 24 were a significant number of correct identifications made. Both of these occurred with washed meat under white light.

DISCUSSION

Crawfish harvests in Louisiana have traditionally consisted of a mixture of two species, the red swamp and white river crawfish. Producers, processors and consumers of crawfish frequently express a preference for one species over another. Preference is generally for red crawfish, based on color and flavor. With increased national and international importance of crawfish as a seafood, it has become important to evaluate the sensory differences between the two species in order to maximize consumer satisfaction and economic opportunities.

Results of Hunter color analysis showed that "fat" from white crawfish is lighter and greener than that of red crawfish, which is darker and more orange. This difference increased during storage, as "fat" from white crawfish became greener. The sensory panel was not able to significantly distinguish between species based on color of "fat". Hunter values indicated a redder color of meat from red crawfish. A difference between species based on color of meat seemed to have been noted by sensory evaluation, though not significantly.

Differences in texture between the species were slight and not significant. Sensory evaluation could not detect significant differences in flavor of meat from the two species, with or without "fat".

These results indicate that species preferences based on color of meat packed with or without "fat" may be an important consideration to processors and consumers. Flavor and texture appear to be very similar, and should probably not be a factor in marketing crawfish meat.

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PROCESSING TIME EFFECTS ON THE TEXTURE OF
FRESH PACKED CRAWFISH MEAT

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INTRODUCTION

Processing crawfish for meat is a rapidly expanding seafood industry. The process involves a partial cook, or blanch, making crawfish easy to peel and devein, while producing a product with a 5-10 day shelf life.

Currently, a variety of processing procedures are being used by more than 60 commercial packers in Louisiana. Variations occur in in cooking time, methods of cooling whole crawfish, and packaging of the meat. The result may be inconsistent quality of fresh and frozen packed products.

One significant problem is mushiness developing in fresh packed meat. This has been thought to be associated with over cooking (4). We felt this textural problem was more associated with insufficient cooking times, as we have noted several occasions in which a processor responded to the problem by cooking less, only to find an increased mushiness as a result. It has also been observed that the tendency to undercook, in the interest of peeling ease and yield, far exceeds the tendency to overcook. Another factor which would suggest undercooking as the source of the textural problem, is the presence of what is thought to be several proteolytic enzymes in the "fat", or hepatopancreas, of the crawfish, which is frequently packed with meat processed for fresh consumption. Hepatopancreatic enzymes have also been implicated in fresh tissue breakdown of the freshwater prawn, Macrobrachium rosenbergii (1), and brown shrimp, Penaeus aztecus (3). If the heat treatment received by crawfish during processing is not sufficient to inactivate these enzymes, proteolytic activity could soften the meat during storage.

The purpose of this study was to evaluate the effect of cooking time on the texture of fresh packed crawfish meat, packed with naturally adhering "fat", so that recommended processing times could be established.

Sample Preparation

Washed live crawfish were cooked in boiling water using simulated commercial procedures. Samples were taken at two minute intervals, from 1 to 13 minutes after crawfish were placed in the boiling water. An uncooked sample was taken as a control. Water returned to a rolling boil approximately seven minutes after addition of crawfish.

All whole crawfish samples were chilled in an ice water slush for approximately two minutes to terminate heat processing. Meat, including naturally adhering "fat", was removed from the tail and placed in whirl pack bags. After being left at room temperature for approximately one hour, as might typically occur throughout a commercial process, the bags of meat were packed in crushed ice for 20 hours.

Samples for sensory evaluation received similar treatment, except as a safety precaution, they were steamed in covered glass containers, then cooled, prior to serving to panelists.

Sample Analysis

Instrumental evaluation of meat texture was done with Instron shear force values. Measurements were made with an Instron Universal Testing Machine (Model 1122), using the Kramer food testing attachment. Crawfish samples were brought to room temperature prior to Instron analysis. Tails were placed randomly in the cell. Testing was done with machine setting of 100 full scale load and 500 cross head speed.

Crawfish were cooked and sampled on three occasions. Five replicate samples from each time interval were analyzed on the Instron in a completely randomized block design. All samples were weighed and the number of tails noted. Peak force values were used to determine the kg/g shear force.

Sensory evaluation of meat texture was done with a nine member panel, which evaluated samples six times using a multiple comparisons test, as described by Larmond (2). Samples had been cooked 1, 3, 7, 11 and 13 minutes prior to storage. Meat cooked seven minutes was used as a reference. Panelists were asked to evaluate all samples, including meat cooked seven minutes, as softer, firmer or no different than the reference. A nine point graduated scale labeled with descriptive terms was used. The panelists' judgements were assigned numerical values from one through nine, from which the statistical analysis was performed.

Simple, preliminary studies were done to evaluate heat stability and activity of what is thought to be proteolytic enzymes in the "fat", responsible for mushiness in meat. A 12% gelatin solution was used as a substrate. For each sample, 0.2 g of "fat" and 5.0 ml of the gelatin solution were mixed, left at room temperature one hour, and then refrigerated at 3°C for 23 hours. Texture was evaluated at 4 and 24 hours, and rated on a 1-4 scale, with 1 and 2 being a thin or thick liquid and 3 and 4 being a soft or firm gel. Proteolytic activity was indicated by all but firm gels.

Statistical Analysis

Statistical analysis was performed in accordance with tests described by Snedecor and Cochran (5). Analysis of Instron data was done by analysis of variance, using a split plot with a randomized block on the main plot. This allowed evaluation of effects of day (batch), cooking time and order of analysis of replicates. Tukey's test was used to analyze critical differences between treatment means.

Analysis of sensory panel data was done by analysis of variance and Tukey's test.

RESULTS

Instron Kramer shear force values showed highly significant differences in texture of crawfish meat due to cooking time and day (batch). Uncooked meat with a shear force of 1.27 kg/g, was significantly firmer than that cooked 1-3 minutes. Shear force decreased with cooking to a mean low of 1.04 kg/g at three minutes. Meat cooked one and three minutes was significantly softer than that cooked five minutes or more. Shear force increased after three minutes to a maximum mean of 1.69 kg/g at seven minutes. There was no significant difference in texture of meat cooked 7-13 minutes. Mean shear force during this period was 1.67 kg/g.

The significant difference in texture between batches was thought to be due to size of tails, with larger tails being firmer. Tails averaged 6.8 g, 2.5 g and 3.0 g in batches 1, 2 and 3, respectively. This correlates with overall shearforce values of the batches, which were 1.93 kg/g, 1.14 kg/g and 1.28 kg/g respectively.

Sensory panel evaluation of texture produced results similar to Instron data. In all tests, meat from crawfish cooked one and three minutes was judged to be significantly softer than that cooked 7, 11 and 13 minutes. In two tests, meat cooked one minute was judged significantly softer than that cooked three minutes, while no such difference was found in the other tests. Meat cooked seven minutes was judged to be the firmest, but was not significantly different from that cooked 11 and 13 minutes.

Tests with the gelatin and "fat" resulted in firm gels when "fat" from crawfish cooked seven minutes or more was used. No gel formation occurred when "fat" was used from crawfish cooked three minutes or less. "Fat" from crawfish cooked five minutes resulted in thick liquids or soft gels, the consistency of which decreased during the 24 hour period.

DISCUSSION

Results of our studies indicated that insufficient cooking time was related to mushiness in fresh packed crawfish meat when packed with "fat", or hepatopancreas. Tests for indication of proteolytic enzyme activity in the "fat" showed that these enzymes seemed to be present and heat labile. Apparent enzyme activity in the "fat" correlated precisely with the development of mushiness in the meat, and appeared to be the cause of the problem.

Uncooked meat was firmer than undercooked meat. This may seem inconsistent, considering the apparently high enzymatic activity in raw "fat", as indicated by the gelatin test. This could be explained by the fact that "fat" remained inside the carapace of raw crawfish, and did not naturally adhere to the meat when peeled. More "fat" adhered to the peeled meat as cooking time increased. This could explain why the mushiest meat occurred at three minutes, when enzymatic activity in the "fat" was apparently still high. Enzymatic activity in the "fat" decreased after three minutes as indicated by the gelatin test. This would explain why meat cooked more than three minutes was firmer, even though more "fat" adhered to it.

Sensory panel evaluation correlated closely with Instron analysis of texture. This indicated that consumers would be sensitive to minor textural problems in crawfish meat. In addition, panelists' comments indicated that the mushiness was very undesirable.

Based on these results, we feel a process can be recommended that will give crawfish processors a consistently high quality product. It appears that at least a seven minute cook, based on a return to boil at seven minutes, is essential. Results also indicate that another six minutes of cooking does not significantly affect meat texture. Preliminary studies indicated that this additional cooking time does not reduce yield. These findings agree with those of Lovell (4). Since cooking time also affects ease of peeling crawfish, processors will need to take this into consideration when establishing how much time to cook. In addition, since there are variations in the cooking methods at different processing plants, processors could evaluate their procedures using a gelatin and fat test similar to the one described here.

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RESIDUAL SULFUR DIOXIDE LEVELS IN ICED AND FROZEN SHRIMP

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INTRODUCTION

The formation of black spot on shrimp is due to the polymerization of tyrosine to the dark pigment melanin. For years the shrimp industry has combatted this problem by dipping shrimp in a solution of sodium bisulfite. The U.S. Food and Drug Administration (FDA) acknowledges the need for this additive, and today regards a one-minute dip in a 1.25% solution of sodium bisulfite (NaHSO_3) as good manufacturing practice. These are the same conditions described in the Codex Code of Practice for Shrimps or Prawns (1975). However, the Codex International Standard allows for a residual level of 100 ppm SO_2 units on raw shrimp meat, while the USFDA this past July stated that "Shrimp in interstate commerce containing greater than 40 ppm sulfite (calculated as SO_2) would be subject to regulatory action such as seizure and/or detention. (They) would, however, give consideration to circumstances" (Anon., 1984).

Only limited information exists on background levels and stability of sulfiting agents in fresh, frozen, and processed shrimp. As early as 1955, Bailey and Fieger reported residual levels of approximately 30 ppm SO_2 in shrimp stored for ten days in 0.1% NaHSO_3 ice. Wood et al. (1976) dipped shrimp according to the Codex conditions, and reported a decrease from 218 ppm to 5 ppm in peeled raw meat after eleven days storage on ice. After fifteen days storage, Weingartner et al. (1977) found a decrease from 65 ppm to 5 ppm residual SO_2 on the peeled muscle of shrimp dipped for five minutes in a 1.25% solution of NaHSO_3 .

The objective of this study was to determine the stability of sulfiting agents in shrimp during ice and frozen storage following treatment with sodium bisulfite according to good manufacturing practice. Samples obtained directly from Gulf shrimp boats were also analyzed for residual SO_2 .

MATERIALS AND METHODS

Brown shrimp (Penaeus aztecus) were harvested from Corpus Christi Bay, placed on ice, and transported to the laboratory in Corpus Christi, Texas. Following rinsing and deheading, approximately ten pounds of shrimp tails were placed in a wire basket and dipped in a 1.25% solution of NaHSO_3 for one minute. They were then rinsed for 15 seconds under fresh water, mixed with ice at a ratio of 1:2, and placed in well-insulated ice chests. Immediately after rinsing and at regular time intervals throughout the storage period, shrimp were removed from the ice chest and analyzed for residual bisulfite according to the modified Monier-Williams procedure (AOAC, 1980).

The sample size used for analysis was 100 grams, and samples were performed in triplicate at each sampling point. During the storage period, sulfite residues were measured on green-headless and peeled shrimp on alternate days. This experimental outline was repeated three times using shrimp of the same species. The accuracy of the analytical procedure was monitored regularly by determining the SO_2 content of analytical grade sodium bisulfite.

In order to determine the stability of residual bisulfite in shrimp during prolonged frozen storage, brown shrimp of size 46-50 tails/pound were treated in 1.25% NaHSO_3 for one minute, and rinsed for 15 seconds. Immediately after treatment, two samples were analyzed for SO_2 , and the remainder were frozen at -26°C ., both as vacuum packed and green-headless glazed portions. At regular intervals samples were removed from the freezer and analyzed for residual SO_2 by the Monier-Williams method.

RESULTS AND DISCUSSION

Tables 1, 2, and 3 show residual levels of SO_2 in shrimp treated with NaHSO_3 and held on ice for one week. In all three trials, SO_2 levels decreased from initial levels of 60-80 ppm to less than 5 ppm after six days. The high initial level shown by unpeeled tails in Table 2 probably reflects greater bisulfite absorption due to poor condition of the shrimp.

Table 1. Residual sulfite in P. aztecus (tail count 61-70)
treated in a 1.25% sodium bisulfite solution for one
minute and held on ice.

DAYS ON ICE	RESIDUAL SO ₂ (ppm)	
	Shell on Tails	Peeled Tails
Initial	125.35	81.99
1 day	66.19	
2 days		27.44
3 days	29.16	
4 days		4.70
5 days	15.05	
6 days		2.99
7 days	9.93	

Each data point represents an average of triplicate samples.

Table 2. Residual sulfite in P. aztecus (tail count 31-35)
treated in a 1.25% sodium bisulfite solution for one
minute and held on ice.

DAYS ON ICE	RESIDUAL SO ₂ (ppm)	
	Shell on Tails	Peeled Tails
Initial	211.40	76.39
1 day	98.33	
2 days		35.87
3 days	49.54	
4 days		18.36
5 days	22.64	
6 days		4.37
7 days	17.83	

Each data point represents an average of triplicate samples.

Table 3. Residual sulfite in P. aztecus (tail count 51-60) treated in a 1.25% sodium bisulfite solution for one minute and held on ice.

DAYS ON ICE	RESIDUAL SO ₂ (ppm)	
	Shell on Tails	Peeled Tails
Initial	92.14	62.14
1 day	39.18	
2 days		17.40
3 days	19.97	
4 days		4.27
5 days	13.13	
6 days		1.92
7 days		

Each data point represents an average of triplicate samples.

After two days the concentrations of SO₂ for all samples were less than half of the initial values, and all were below the 40 ppm residual level required by the USFDA. This rapid reduction was primarily due to the leaching effect of the melting ice, which was also reported by Weingartner et al. (1977).

Table 4 shows the stability of sulfiting agents in vacuum packed and green-headless glazed shrimp during frozen storage. Here the level of SO₂ units in treated shrimp remains fairly constant during prolonged frozen storage.

Table 4. Residual sulfiting agent (ppm SO₂) in shrimp during prolonged storage.

TIME OF STORAGE	RESIDUAL SO ₂ (ppm)	
	Vacuum packed	Glazed
Initial		53.17
Two weeks	59.10	48.05
One month	59.10	48.05
Two months	57.34	62.46
Three months	64.87	57.33

Each data point represents an average of duplicate samples.

A large number of shrimp samples were obtained directly from boats along the Texas Gulf coast. These were frozen in ziplock sandwich bags and analyzed later for residual bisulfite. The level of SO_2 as determined by the Monier-Williams method ranged from 2 ppm to 571 ppm, with a mean residual level of 96 ppm.

CONCLUSIONS

These results show that for shrimp treated with sodium bisulfite on-board, according to good manufacturing practice and placed on ice, low levels of residual SO_2 are to be expected at the time of landing. However, for shrimp treated in the same manner then rinsed and frozen, residual SO_2 on the peeled tails should be between 50 to 100 ppm. If a dip in 1.25% NaHSO_3 solution for one minute is regarded as part of the good manufacturing practice for shrimp processing, it would be more logical to adapt the Codex International Standard which allows 100 ppm on raw shrimp meat rather than the 40 ppm as suggested by the USDA.

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A COMPARISON OF METHODS
FOR DETERMINING SULFUR DIOXIDE
IN SHRIMP

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INTRODUCTION

Sulfur dioxide is a reducing agent used to prevent melanosis or black spot on shrimp. Due to recent medical evidence that sulfur dioxide causes severe allergic reactions in asthmatics, its use in foods has come under close scrutiny by regulatory authorities. In order to determine whether shrimp have been treated according to GMP's or whether they have been overtreated, regulatory agencies must use the modified Monier-Williams method (AOAC, 1980) for estimating sulfur dioxide. This method is extremely tedious and thus limits the number of samples that can be tested.

Researchers have developed other methods for determining SO₂ in foods that are more rapid but lack either the quantitative aspect or the consistency of the Monier-Williams procedure. Some of these are the lead acetate strip procedure (AOAC, 1980), the malachite green method (Kaplan, 1961), the p-rosaniline procedure of the (AOAC, 1980) and the double enzyme test developed by Boehringer Mannheim Biochemicals (1983).

In order to develop a more convenient method for the determination of residual SO₂ in shrimp, we tested modified versions of the p-rosaniline and enzymatic methods and compared them to the Monier-Williams method on shrimp containing various levels of residual SO₂.

MATERIALS AND METHODS

Fresh, nontreated shrimp (i.e. no bisulfite treatment) were obtained from boats in the Port Aransas, Texas area. The shrimp were transported to the Seafood Technology Laboratory at Texas A&M, headed and sorted into groups according to size and species. They were given a 1 minute dip in a 1.25% sodium bisulfite solution, rinsed for 5 seconds in running tap water and frozen in 5 pound boxes until tested. Prior to analysis, the shrimp were thawed overnight at 4°C and peeled.

The flow chart in figure 1 shows the overall experimental design. For each sample, 220 grams of edible meat was blended with

220 grams of water for one minute in a Waring blender. This homogenate was then divided into 3 parts: (1) 200 grams were tested using the Monier-Williams procedure described in the AOAC (1980), (2) 40 grams were tested using the p-rosaniline procedure as described in the AOAC (1980) and (3) 200 grams were placed in frozen storage in whirl-pak bags for extraction (as described below) when time permitted.

The frozen samples (whirl-pak bags) were thawed overnight at 4°C and then rinsed into blender jars for extraction. Using a variable auto transformer to produce a continual vortex, 50 ml of 1 N NaOH was slowly added to the sample to bring the pH to approximately 11.66. After blending at this pH for 1 minute, 50 ml of 1 N HCL was added to bring the sample to near the original pH. After 30 seconds of blending, the homogenate was poured into a 250 ml centrifuge bottle and centrifuged on an IEC B-20A Centrifuge for 30 minutes at 10,000 RPM. The supernatant was removed and tested for SO₂ by the enzyme method described by Boehringer Mannheim Biochemicals (1983) and the p-rosaniline procedure of the AOAC (1980). By recording all added water and assuming equal distribution of the SO₂ throughout the samples, only a portion of the homogenate was needed for the analysis.

RESULTS AND DISCUSSION

The results of the four analyses are shown in Table 1. The sulfur dioxide estimates for the modified Monier-Williams procedure ranged from 59.26 to 88.08 ppm. This range is in agreement with work reported by Wagner and Finne (1985) for shrimp dipped in a 1.25% sodium bisulfite solution for 1 minute. The estimate for the other three procedures were all higher than the Monier-Williams procedure. For the initial p-rosaniline and the extract p-rosaniline, the ranges were 73.89 to 121.03 ppm and 61.68 to 116.53 ppm, respectively. The range for the enzyme procedure was 82.28 to 132.41 ppm SO₂.

These ranges indicate that the modified Monier-Williams procedure does not recover all of the SO₂ that is present. Unpublished results from our lab show that this procedure recovers less than 50% of the SO₂ on shrimp spiked with sodium bisulfite. Comparing overages, the two p-rosaniline procedures both recovered approximately 24% more sulfur dioxide than the Monier-Williams procedure, where the enzyme procedure recovered 48% more. This may indicate that the bound SO₂ in shrimp does not dissociate readily at the low pH of the Monier-Williams procedure.

Figures 2, 3 and 4 show the plots of the initial p-rosaniline, the extract p-rosaniline and the enzyme procedures versus the Monier-Williams procedure, respectively. These data were analysed using simple linear regression to determine the correlation between

the various methods and the Monier-Williams procedure. Due to lack of homogeneity between the samples, no other statistical analysis was performed.

The correlation coefficient for the initial p-rosanaline procedure versus the Monier-Williams procedure was 0.68. The value for the extract p-rosanaline procedure was 0.19. However, by eliminating the outlying data point at (87.76, 61.68), the correlation coefficient for this method versus Monier-Williams went to 0.56. Therefore these two methods are very similar in their ability to predict SO_2 concentrations in shrimp. The problem with them is that they are not effective enough to be a desirable alternative to the Monier-Williams procedure.

The regression analysis for the enzyme method versus the Monier-Williams method gave a correlation coefficient of 0.33. However, there are three obvious outlying data points that can be seen in figure 4. Eliminating these three points gives a correlation coefficient of 0.91. This would therefore be an effective method if the reason for the variability of these three points could be determined.

In conclusion, the three methods that were evaluated in this study appear to be ineffective in replacing the Monier-Williams procedure for estimating SO_2 in shrimp. However, of the three, the enzyme method could possibly be used if the obvious variability can be eliminated.

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Figure 1. Flow chart for sulfur dioxide analysis of shrimp.

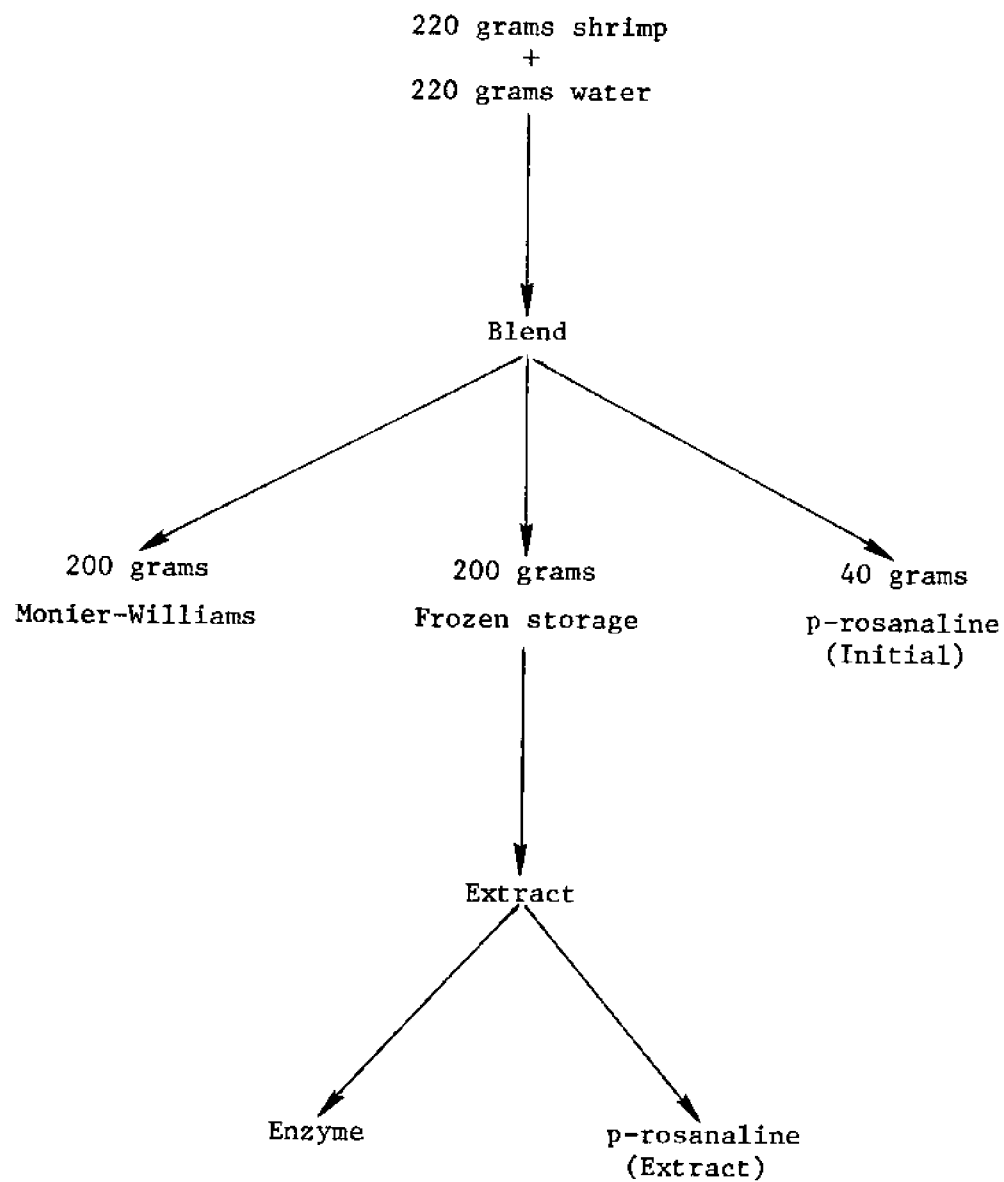


Table 1. Estimation of ppm sulfur dioxide in peeled shrimp using four methods.

Sample Description	Monier-Williams	Initial p-rosaniline	Extract p-rosaniline	Enzyme
1. Small whites	84.88	104.47	109.90	116.67
2. Small whites	88.08	121.03	116.53	125.93
3. Large whites	67.26	73.89	106.39	132.41
4. Small whites	87.76	101.28	61.68	82.28
5. Small whites	59.26		91.13	110.98
6. Small pinks	73.67	102.53	94.38	111.27
7. Small browns	80.08	91.73	95.36	128.47
8. Small browns	76.23	91.73	97.25	118.15
9. Small pinks	62.46	80.90	89.50	89.41
10. Small browns	78.47	92.37	108.49	118.60
11. Small pinks	70.47	86.21	92.74	102.10
12. Small pinks	67.26	82.17	86.49	87.39
13. Small whites	84.88	105.11	92.83	125.85
14. Large whites	86.48	83.49	101.02	122.94
15. Large whites	68.86	95.55	73.42	93.64
Mean $\pm$ S.D.	75.74 $\pm$ 9.55	93.75 $\pm$ 12.38	94.47 $\pm$ 13.99	111.07 $\pm$ 16.30

Figure 2. Plot of initial p-rosaniline versus Monier-Williams for estimation of sulfur dioxide on peeled shrimp.

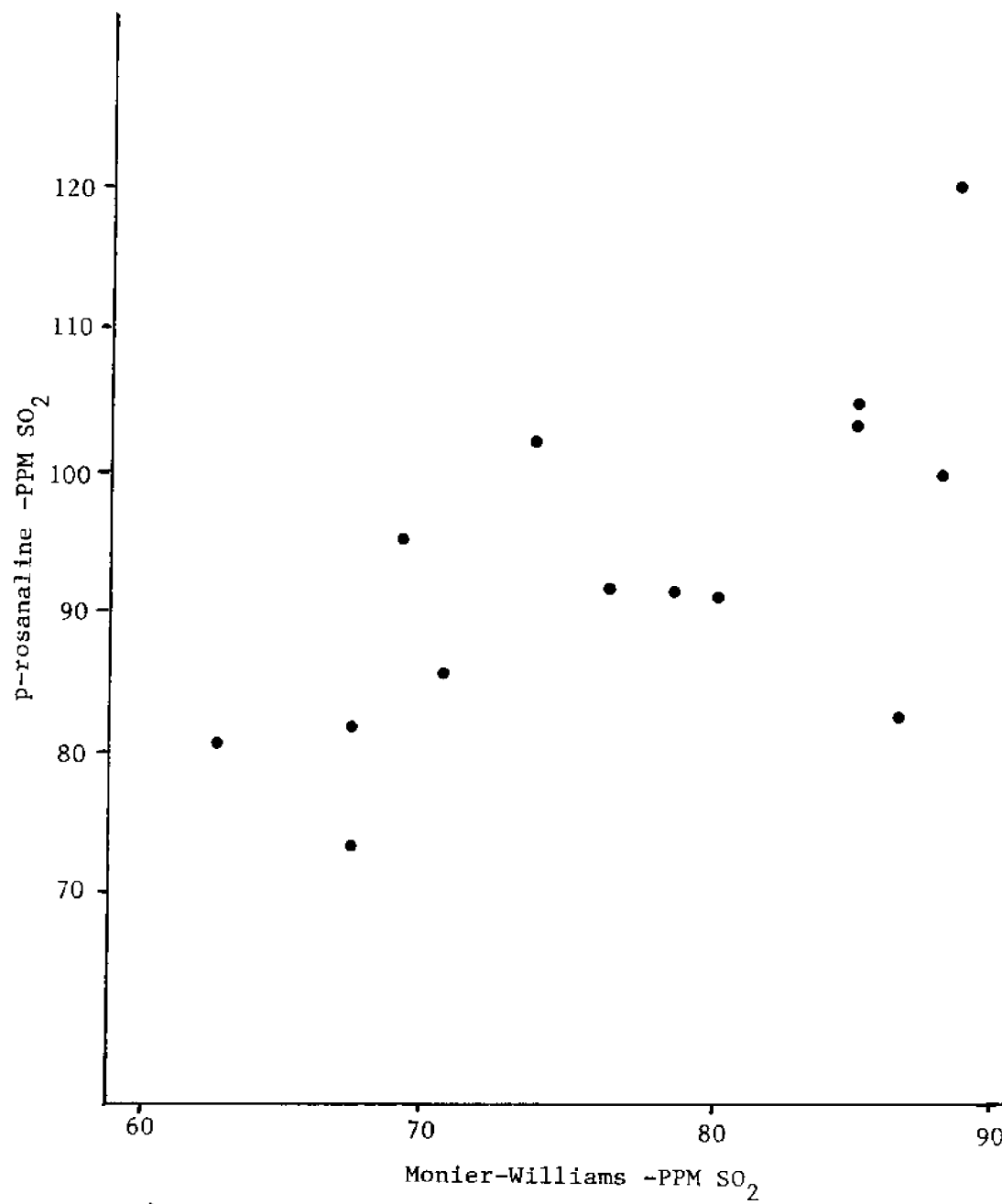


Figure 3. Plot of extract p-rosaniline versus Monier-Williams for estimation of sulfur dioxide on peeled shrimp.

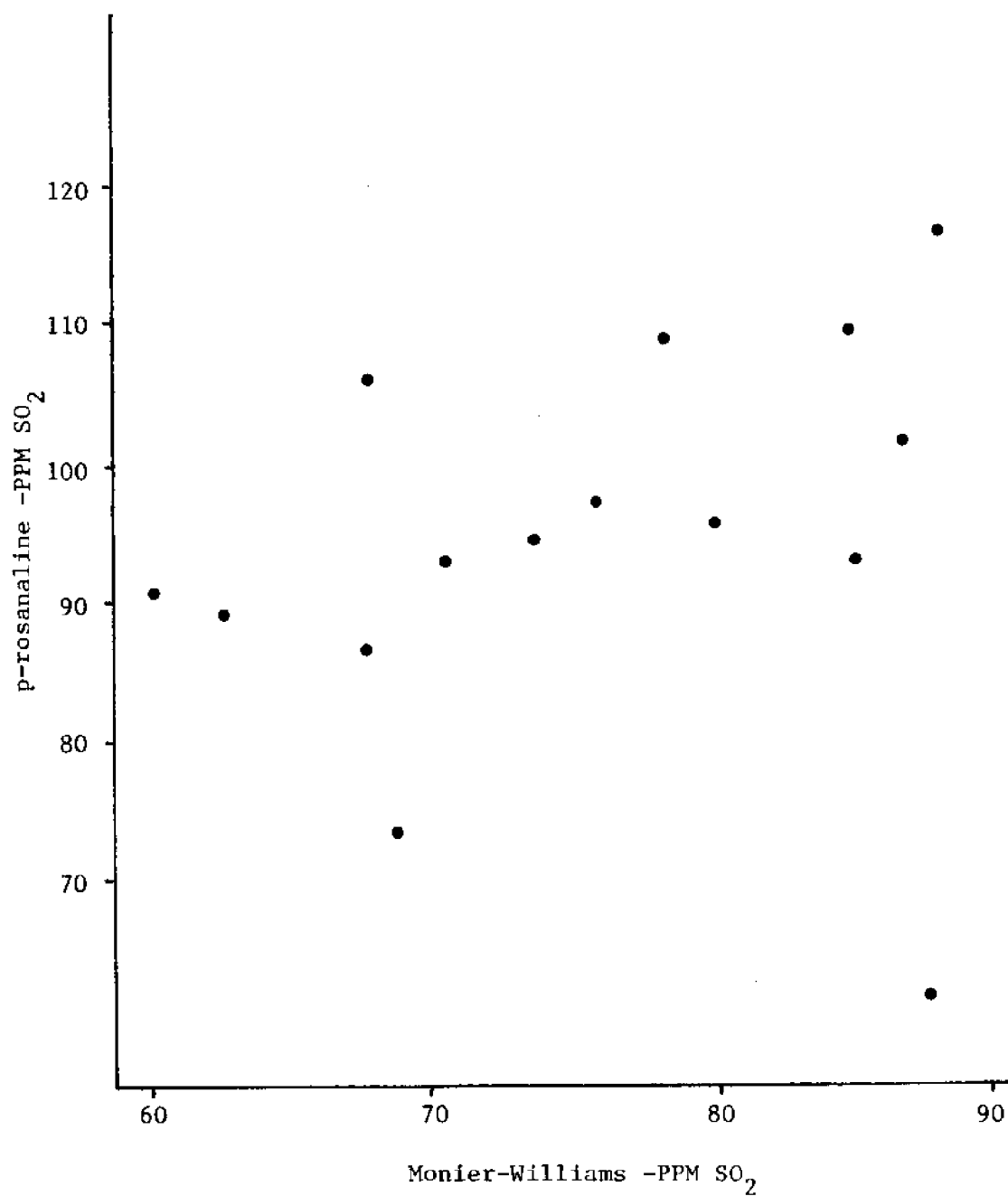
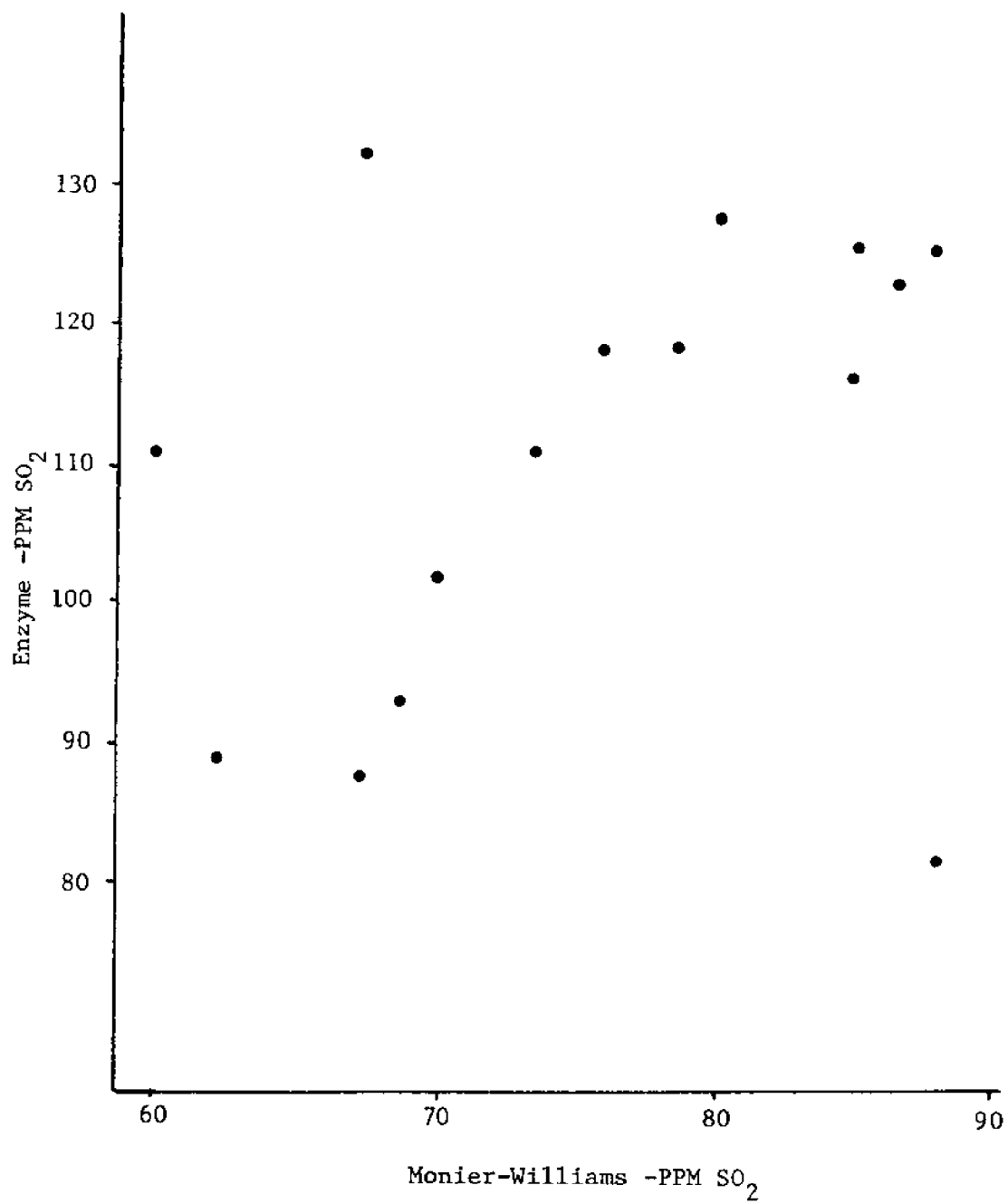


Figure 4. Plot of enzyme versus Monier-Williams for estimation of sulfur dioxide on peeled shrimp.



Preliminary Study on the Use of Ion Chromatography to Measure Residual Sulfite Levels in Shrimp

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Introduction

Freshly caught shrimp are often dipped in a sodium bisulfite (NaHSO_3) solution (1.25% w/v, 1 min) to prevent the formation of black spot or melanosis (Camber et al., 1957). Recently the use of sulfiting agents as food additives has come under scrutiny due to possible adverse health affects. Sulfiting agents have been associated with the initiation of asthmatic reactions in certain sensitive individuals (Taylor and Bush, 1983). The FDA has proposed limiting the acceptable level of residual sulfite on shrimp to 40 ppm as SO_2 (Food Chemical News, 1984). The AOAC method for analysis of sulfites in food is the Modified Monier-Williams Method (AOAC, 1980). The Monier-Williams method requires an 1.75 hour acid distillation of the sample. The objective of this study was to develop from existing methodology, an ion chromatographic (IC) method (Anderson et al., 1983) for determining residual sulfite in shrimp. The advantage of this method would be the shorter amount of time required for analysis. Analysis by IC requires approximately 20 minutes versus the AOAC method which requires almost two hours.

Materials and Methods

Materials

Headless shrimp samples were either treated with a 1.25% (w/v) sodium metabisulfite solution ($\text{Na}_2\text{S}_2\text{O}_5$) for one minute prior to peeling or spiked at various levels (30, 50, 100, 150, 200, 500 ppm $\text{Na}_2\text{S}_2\text{O}_5$) with standards after peeling and homogenization. Appropriate dilutions of a 1000 ppm $\text{Na}_2\text{S}_2\text{O}_5$ solution were made so that one ml of each spiking solution contained the desired amount of $\text{Na}_2\text{S}_2\text{O}_5$. All shrimp were peeled prior to analysis and homogenized in a Waring Blender for three one second bursts.

Methods

Analysis for sulfite was done using the standard AOAC Modified Monier-Williams procedure (AOAC, 1980) and one of two ion chromatographic methods, one involving an acid distillation and the other an alkaline formaldehyde extraction.

Acid Distillation

Two to ten grams of homogenized shrimp were weighed into a 100 ml, two neck boiling flask. When standards were run, only the spiking solution was added to the flask. Shrimp used for recovery studies were spiked after addition to the flask. The boiling flask was swept with nitrogen for approximately two minutes. Distillation was initiated by addition of 50 ml of 8N phosphoric acid through a pressure equalizing dropping funnel and

heating in a mantle under a continuous flow of nitrogen. A solution of 0.1 N sodium hydroxide containing 0.1% formaldehyde, held in an ice bath, was used to trap free sulfur dioxide (SO_2) during distillation. The shrimp/acid mixture was allowed to boil for one minute and then the heating mantle was unplugged. The nitrogen was allowed to flow through the apparatus for six minutes after boiling was initiated for a total reaction time of ten to twelve minutes. The trapping solution was diluted to volume with the same solution and a portion used for injection.

Alkaline-Formaldehyde Extraction

Two to five grams of homogenized shrimp were weighed into centrifuge bottles and 100 ml of 0.1 N sodium hydroxide containing 0.1% formaldehyde was added. Samples were homogenized in solution using a Brinkmann Polytron (setting 7, 30 sec), centrifuged (7000 rpm, 5 min) and filtered (Whatman #4). A portion of the filtrate was extracted with an equal volume of methylene chloride, centrifuged (7000 rpm, 5 min) and a portion of the aqueous phase used for injection. All samples were filtered through a 0.45 μm membrane filter (Gelman) prior to injection.

A Dionex model 2010i ion chromatograph equipped with a 50 μl sample loop, Dionex HPIC-AS3 ion exchange separating column, fiber suppressor, conductivity detector, and pulsed amperometric detector with a silver electrode was used to determine sulfite. The pulsed amperometric detector was operated with an applied potential of either +0.30 for the alkaline-formaldehyde extracted samples or +0.40 volts for the acid distillation samples and output range of 30 nA, while the conductivity detector was operated at an output range of 3 uSiemens. The flow rate was 2.5 ml/min with 3mM NaHCO_3 /1.5 mM Na_2CO_3 eluent. Standards were run daily using freshly made solutions containing 5, 10, 15, 20, and 25 ppm $\text{Na}_2\text{S}_2\text{O}_5$ in trapping solution (0.1 N NaOH/0.1% HCHO).

Results

A comparison was made of the recoveries of sulfite standards using the Monier-Williams method and the acid distillation-IC method (AD-IC). Results of the experiment are shown in Table 1. The recovery of sulfite standards using the two methods showed correlation. The recovery values obtained using the AD-IC method averaged 98% of the values obtained by the Monier-Williams method. The Monier-Williams method was less precise at low levels (0.3 - 1.0 mg) of added sulfite than the AD-IC method.

Table 1. % Recovery of Added Standards by the Monier-Williams and the Acid distillation IC methods

mg $\text{Na}_2\text{S}_2\text{O}_5$ added	mg as SO_2 added	Monier-Williams % recovery (+SD)	Acid Distillation-IC % recovery (+SD)
30	20	55.8 (17.8)	52.3 (7.3)
50	33	65.8 (18.5)	73.2 (2.4)
100	67	92.0 (24.5)	77.7 (1.7)
150	101	77.9 (3.4)	77.5 (7.0)
200	135	81.9 (2.0)	84.2 (4.3)
500	336	89.8 (6.0)	91.3 (1.7)

In a preliminary experiment various concentrations of phosphoric acid (2,4,8 N) were used in order to determine which concentration yielded the most efficient extraction of sulfite from the shrimp matrix (Table 2). Recovery of sulfite from shrimp was increased from 50% to 70% at specified levels (50, 100, 500 ppm $\text{Na}_2\text{S}_2\text{O}_5$) of sulfite when 8 N phosphoric acid was used rather than the 2N suggested by Anderson et al. (1983).

Table 2. % Recoveries of standards (+SD) from homogenized shrimp using the acid distillation-IC method, with various concentrations of phosphoric acid.

ppm $\text{Na}_2\text{S}_2\text{O}_5$ added	ppm as SO_2 added	2 N	4 N	8 N
50	33	47.1 (6.4)	56.6 (3.3)	70.0 (9.0)
100	67	51.8 (2.6)	59.8 (5.8)	71.2 (2.2)
500	336	51.9 (3.4)	62.1 (1.0)	76.3 (1.1)

A comparison of the recovery of sulfite from shrimp spiked with various levels (30-500 ppm $\text{Na}_2\text{S}_2\text{O}_5$) of sodium metabisulfite was determined using the Monier-Williams and the AD-IC methods (Table 3). The AD-IC method consistently gave lower recovery values for the sulfite. Recovery values obtained using the AD-IC method averaged 85% of those obtained with the Monier-Williams procedure. Recovery values obtained by the AD-IC method were more precise at all levels of added sulfite except the highest (500 ppm $\text{Na}_2\text{S}_2\text{O}_5$).

Table 3. % Recoveries of $\text{Na}_2\text{S}_2\text{O}_5$ standards added to 10 grams of homogenized shrimp by the Monier-Williams and the Acid Distillation-IC procedures.

ppm $\text{Na}_2\text{S}_2\text{O}_5$ added	ppm as SO_2 added	Monier-Williams % recovery (+SD)	Acid Distillation-IC % recovery (+SD)
30	20	40.3 (13.5)	47.4 (4.9)
50	33	59.9 (9.6)	50.5 (7.0)
100	67	70.5 (4.4)	53.7 (2.1)
150	101	67.4 (7.5)	56.7 (2.8)
200	135	79.0 (3.2)	61.5 (2.2)
500	336	84.2 (1.5)	63.5 (2.2)

Shrimp treated with a 1.25% (w/v) sodium metabisulfite dip for one minute were analyzed for residual sulfite by the Monier-Williams and AD-IC method. Residual sulfite as determined by the Monier-Williams method averaged 167 ppm as SO_2 . The AD-IC method was applied using three different sample sizes consisting of two, five and ten grams of dip treated homogenized shrimp each. The values obtained were 37.0 ppm SO_2 for the ten gram sample, 54.3 and 62.8 ppm SO_2 for the five and two gram samples respectively. The ten gram samples of shrimp were subjected to a second acid distillation and it was found that additional sulfite could be extracted. These results indicate that the conditions of the acid distillation used for the IC method result in an incomplete extraction of sulfite from the shrimp matrix.

An alkaline formaldehyde extraction was also used in conjunction with ion chromatography for analysis of sulfite in shrimp. Sample chromatograms are shown of shrimp extracts prepared from, sulfite dip treated shrimp and shrimp which were not treated with any sulfiting agents (Fig. 1). Shrimp treated with a 1.25% (w/v) $\text{Na}_2\text{S}_2\text{O}_5$ dip for one minute were analyzed for residual sulfite by both the Monier-Williams and the alkaline formaldehyde extraction-IC (AFE-IC) methods (Table 4). Residual sulfite as determined by the Monier-Williams method averaged 147 ppm as SO_2 and 155 ppm as SO_2 for the AFE-IC method. The AFE-IC method appears to give a much better correlation with the Monier-Williams method than the AD-IC method does.

Table 4. Determination of residual sulfite as SO_2 in shrimp dipped in 1.25% $\text{Na}_2\text{S}_2\text{O}_5$ for one minute. Values are the results of 3 experiments, 2 replicates each.

	PPM SO_2	
Alkali Extract, IC		Monier-Williams
153		118
160		167
154		156

In another experiment, small (60 count/lb) and large (28 count/lb) shrimp were treated with a 1.25% (w/v), 1 min $\text{Na}_2\text{S}_2\text{O}_5$ dip. Residual sulfite on the shrimp was then analyzed by the Monier-Williams and the AFE-IC methods. The Monier-Williams method yielded values of 242 and 123 ppm SO_2 for the small and large shrimp respectively. Results of the AFE-IC method were 247 ppm SO_2 for the small shrimp and 67 ppm SO_2 for the large shrimp.

Discussion

The recovery of $\text{Na}_2\text{S}_2\text{O}_5$ standards in the absence of shrimp indicates a good correlation between the Monier-Williams method and the AD-IC methods. The results show that the precision is better with the AD-IC method at low levels of added sulfite compared to the Monier-Williams method. The levels of sulfite used were below the sensitivity limit for the Monier-Williams method ($> 40 \text{ mg SO}_2$).

A comparison of the recovery of sulfite from shrimp using the Monier-Williams and AD-IC methods show that recoveries are consistently lower for the AD-IC method. Recovery of sulfite from shrimp using the Monier-Williams method on the average were 10% lower than the recovery of sulfite in water alone. The decrease in recovery may be attributed to some irreversible binding of sulfite to the shrimp matrix. Recovery of sulfite from shrimp using the AD-IC method was approximately 20% less than the recovery of sulfite from the model water system. The decrease in recovery may be accounted for by some irreversible binding as well as incomplete extraction of sulfite from the shrimp. The ten minute acid distillation is not sufficient to completely digest and release sulfite present when working with shrimp. Preliminary experiments indicated that recovery was improved by using more concentrated phosphoric acid. The higher concentration of phosphoric acid however, still did not provide equivalent recoveries.

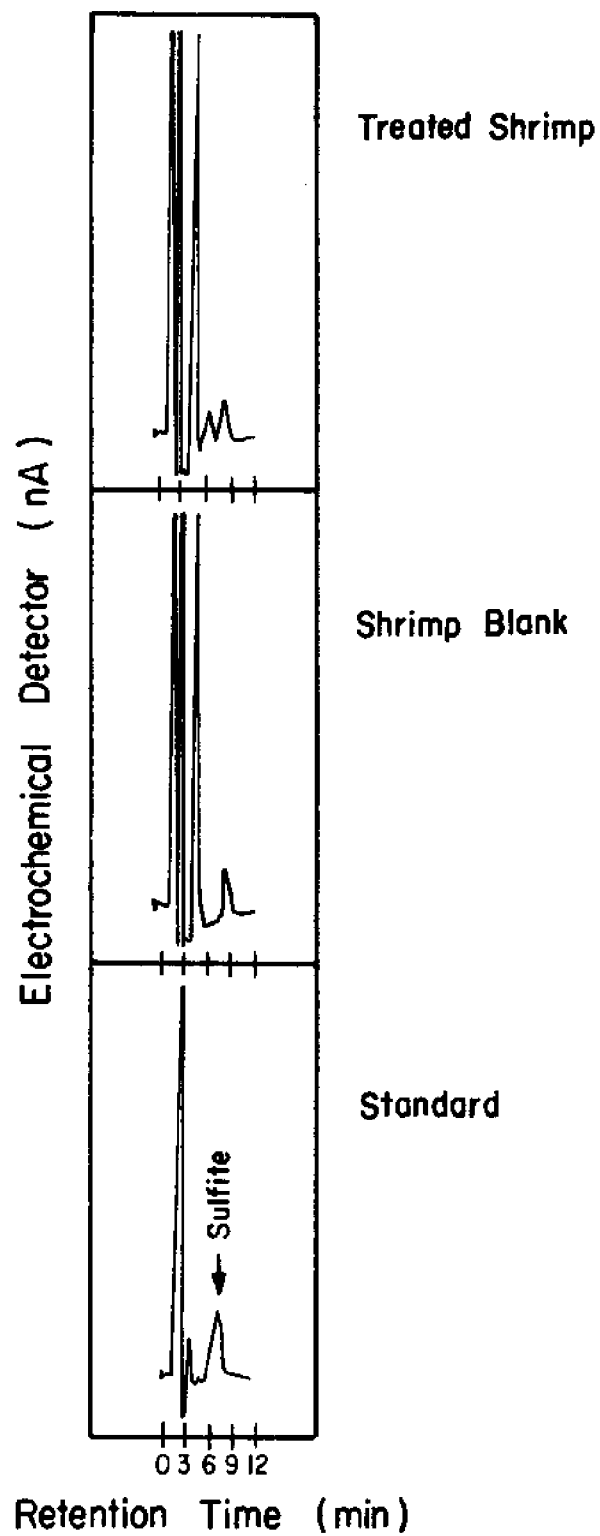


Fig. 1. Chromatograms of shrimp treated with a 1.25%, one minute $\text{Na}_2\text{S}_2\text{O}_5$ dip (top), untreated shrimp (middle), and sulfite standard (bottom). IC conditions; AS-3 column, pulsed amperometric detector (+.30 V applied potential), 3mM NaHCO_3 / 1.5mM Na_2CO_3 , flow (2.5 ml/min).

Further experiments using $\text{Na}_2\text{S}_2\text{O}_5$ dip treated shrimp showed that levels of residual sulfite as determined by the AD-IC method were significantly lower than the values obtained using the Monier-Williams method. The AD-IC procedure was used on three different sample sizes of the dip treated shrimp. As the sample size decreased the values obtained for residual sulfite increased indicating a better extraction of sulfite with smaller sample sizes. Analysis of a ten gram sample using the AD-IC method resulted in a value that was only 22% of that obtained by the Monier-Williams method. When the sample size of shrimp was decreased to two grams, the residual level of sulfite was determined to be 62 ppm as SO_2 or 37% of the value obtained by the Monier-Williams method. The acid distillation procedure used in conjunction with ion chromatography is insufficient for releasing all reversibly bound sulfite. The extraction of sulfite may be improved by heating for a longer period of time, this would have to be accompanied by a modification if the distillation apparatus to include a condenser.

Results of the comparison of the Monier-Williams method with the alkaline formaldehyde extraction-IC method indicate a good correlation between the two. The alkaline-formaldehyde extraction of sulfite from shrimp appears to be much more efficient than the acid distillation for the release of sulfite. The AFE-IC method resulted in values that averaged 107% of the values obtained by the Monier-Williams method. An advantage of AFE-IC method is the shorter time required for analysis compared to the Monier-Williams method.

Residual levels of sulfite were found to differ considerably between small shrimp (60 count/lb) and large shrimp (30 count/pound) after treatment with a 1.25% $\text{Na}_2\text{S}_2\text{O}_5$, 1 minute dip. The level of residual sulfite on the small shrimp was almost twice the level found on the large shrimp. All shrimp samples were analyzed by both the Monier-Williams and the AFE-IC methods. These methods yielded similar results.

Conclusions

The acid distillation-ion chromatographic method for the analysis of sulfite is comparable to the Monier-Williams method when applied to standard solutions. The conditions of the acid distillation are not severe enough for the complete extraction of sulfite when applied to the analysis of shrimp. The alkaline-formaldehyde extraction of sulfite from shrimp accompanied by ion chromatographic analysis has been shown to give results comparable to those obtained by the AOAC Monier-Williams method in a shorter time. Further work must be completed to establish and confirm these findings. Further study is also needed to more fully determine the relationship of shrimp size to levels of residual sulfite after typical commercial sulfite dip treatment.

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A PRELIMINARY PROCEDURE FOR THE DETECTION OF CONDENSED PHOSPHATES IN SHRIMP USING THIN-LAYER CHROMATOGRAPHY

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INTRODUCTION

Polyphosphates are used extensively in meats, poultry and seafoods for their multifunctional advantages. Among the advantages claimed: reduction in weight loss during frozen storage, less toughening of the product and less loss in weight during cooking (Ellinger, 1972). At the present time, the increase in the use of polyphosphates in seafood industry is largely due to its variety of applications. For example, the shrimp and shellfish processors use polyphosphates to improve the yield and quality of the final product. Of the numerous types of polyphosphates, the linear condensed phosphates pyro and triphosphates were found to be very effective in reducing thaw drip in unfrozen seafood muscle. However, there are indications that these condensed phosphates gradually hydrolyze in muscle to monophosphate during prolonged frozen storage (Gibson and Murray, 1973).

In order to determine the stability of linear phosphates in frozen muscle, it is essential that the added phosphates can be detected and accurately determined during frozen storage. Many of the thin-layer chromatographic methods that exist in the literature are either not sensitive enough towards detection or are difficult to analyze for phosphorus levels accurately.

The objectives of this study were to: (a) determine the sensitivity of the proposed method for the detection of added phosphates in shrimp by thin-layer chromatographic separation and (b) analyze the condensed phosphate mixtures containing varying percentages of mono-, pyro-, and triphosphates.

MATERIALS AND METHODS

Preparation of standard phosphate solutions

Sodium monophosphate (Na_2HPO_4), sodium pyrophosphate ($\text{Na}_4\text{P}_2\text{O}_7$) and sodium triphosphate ($\text{Na}_5\text{P}_3\text{O}_{10}$) solutions were prepared to contain 1-5 $\mu\text{g}/\mu\text{l}$.

Treatment of shrimp

Fresh white shrimp (*Penaeus setiferus*), (30-40 tails per pound) were used in this study. One half of the deheaded, peeled shrimp received sodium triphosphate (STP) treatment (0.5%, w/w) while the other half remained untreated. Treated shrimp were evaluated for condensed phosphates.

tes during the first (0 week) and then at one week intervals through six weeks of frozen storage (-25 C).

Preparation of extract

Shrimp (50 g) were homogenized for 1 min with distilled water as the extraction medium (1:2). The resulting slurry was then filtered under suction through a Whatman #1 filter paper.

Thin-layer chromatography

TLC separation was carried out on glass plates (20x20 cm) coated with MN 300 HR cellulose (Brinkman Instruments, Inc., NY) to a layer thickness of approximately 100 μ . After activation period of 3 hrs at 105 C, the plates were stored in a desiccator until needed (no more than a few hours). Standards and the samples were applied about 25 mm from the lower edge of plate as spots, approx. 3-5 mm in diameter (4-5 μ l) and the plates inserted into TLC tank containing a solvent mixture with the following composition: 2 g ammonium carbonate, 160 ml acetonitrile and 90 ml p-toluenesulfonic acid. Tank was then covered with a lid. Plates were developed inside the tank which was kept saturated with the solvent atmosphere. When the solvent front has ascended approx. 10 cm from the origin of the sample, plates were removed from the tank and dried in the oven until the solvent has evaporated completely from the plates.

Detection of phosphates

Dried plates were placed vertically under a fume hood and sprayed lightly but uniformly with a developing solution. This solution can be prepared by dissolving the following reagents in 1 liter of distilled water. (1) ammonium sulfate, 50 g, (2) ammonium molybdate, 75 g, and (3) conc. nitric acid, 150 ml. After drying at 55-60 C in the oven for a period of 8-10 min, the plates were allowed to cool before being sprayed with a mixture consisting of 288 g of sodium pyrosulfite, 10.5 g of sodium sulfite and 1 g of methylaminophenol dissolved in a liter of distilled water. The latter spray helps in reducing the yellow spots detected during the initial spray to blue spots so that detection can be improved considerably.

Hydrolysis of sodium triphosphate and analysis of mixtures

Once the separation and identification of condensed phosphate spots on the chromatogram have been carried out, the amount of phosphorus in each spot was determined by colorimetric method suggested by Crowther (1955). The procedure consists of cutting out the spots, soaking them with ammonium hydroxide to elute phosphates and hydrolyzing sodium triphosphate and pyrophosphate to monophosphate in the presence of conc. sulfuric acid. The absorbances for monophosphates were read at 830 nm using a Bausch and Lomb spectronic 21 DV spectrophotometer. From the absorbances the amount of phosphorus present in a given mixture was calculated from a previously prepared standard curve which was obtained by using the standard solutions of sodium monophosphate.

RESULTS AND DISCUSSION

Good separations were obtained for the condensed phosphates with the new TLC procedure. Calculated R_f values for standard phosphate solutions are presented in Table 1. Sodium pyrophosphate and sodium triphosphate migrated very well as indicated by high R_f values. For the triphosphate standard faint pyrophosphate and monophosphate spots were evident on the developed plate at the R_f values of pyrophosphate and monophosphate, respectively. This suggests that some hydrolysis of triphosphate will take place during TLC analysis. Physical and chemical characteristics of individual components in a solvent system, phase

Table 1. R_f values of condensed phosphates as measured by the proposed method and by the method of Rossel (1963).

PHOSPHATE SPECIES	STANDARDS RUN INDIVIDUALLY			STANDARDS RUN AS A MIXTURE		
	Mono	Pyro	Tri	Mono	Pyro	Tri
Proposed method	0.83	0.71	0.59	0.86	0.67	0.51
Literature method	0.92	0.68	0.44	0.86	0.62	0.38

interactions (solvent-sorbent, solvent-solute interactions), acidity (pH) and strength of solvent are some of the variables in the mobile phase system that were reported to affect chromatographic separation and migration rates (Snyder, 1968; Touchstone and Dobbins, 1978). Thus, the differences noted in R_f values between the two methods tested could be to some extent, the result of the inherent nature of the different mobile phases used for TLC separation.

Figure 1 shows the relative migration distances of condensed phosphates on a TLC plate. Migration rates for sodium monophosphate were found to be consistently higher than either pyrophosphate or triphosphate. Rates were slightly affected when the phosphates were separated in presence of each other.

After the phosphates were separated and detected at various concentrations on standard plate according to the discussed procedure, the sensitivity of the method was investigated for added phosphates in treated shrimp. Several treatment levels ranging from 0.08-0.50% (w/w) were used in this investigation. Although the phosphates were detected at the lowest treatment level (0.08%,w/w), the detection at lower levels of treatment was only in the form of faint spots (Figure 2).

On the basis of above findings, the stability of condensed phosphates

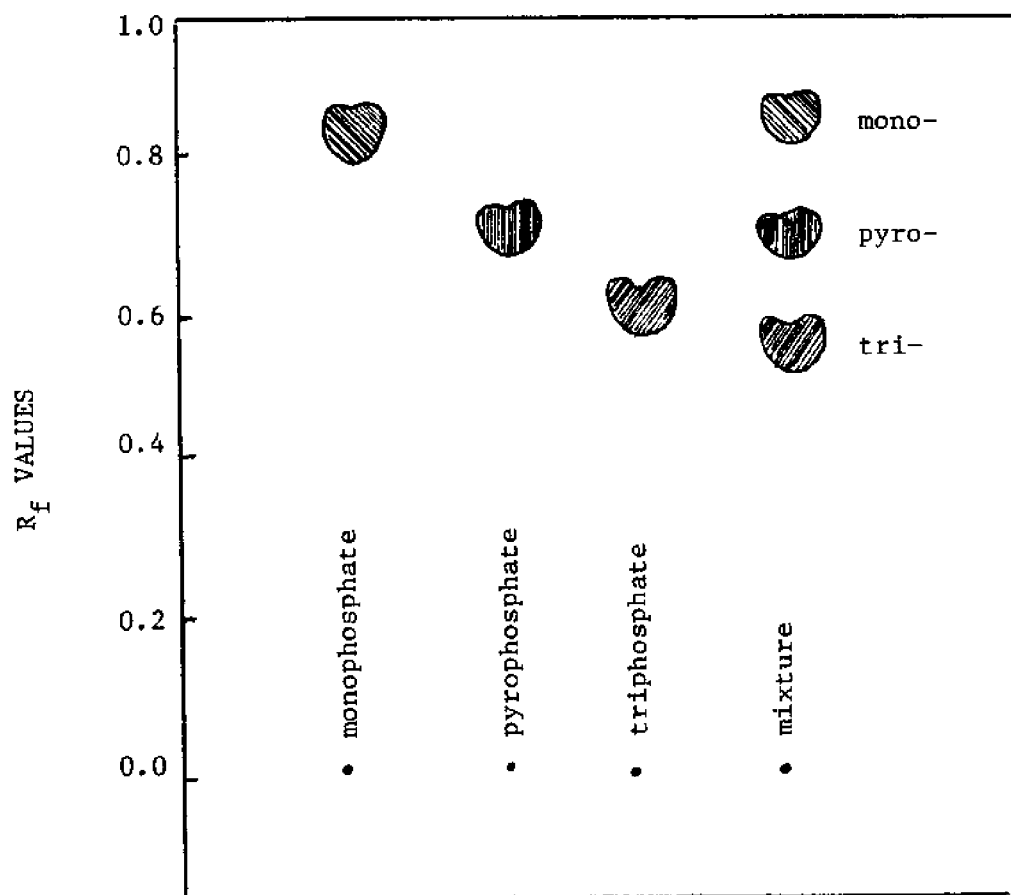


Figure 1. Thin-layer chromatogram of standard condensed phosphate solutions. Stationary phase - cellulose. Mobile phase - ammonium carbonate-acetonitrile-toluenesulfonic acid. Concentrations of solutions and the mixture - 250 mg per 100 ml water. Phosphates were detected as blue spots by means of ammonium molybdate and sodium sulfite solutions.

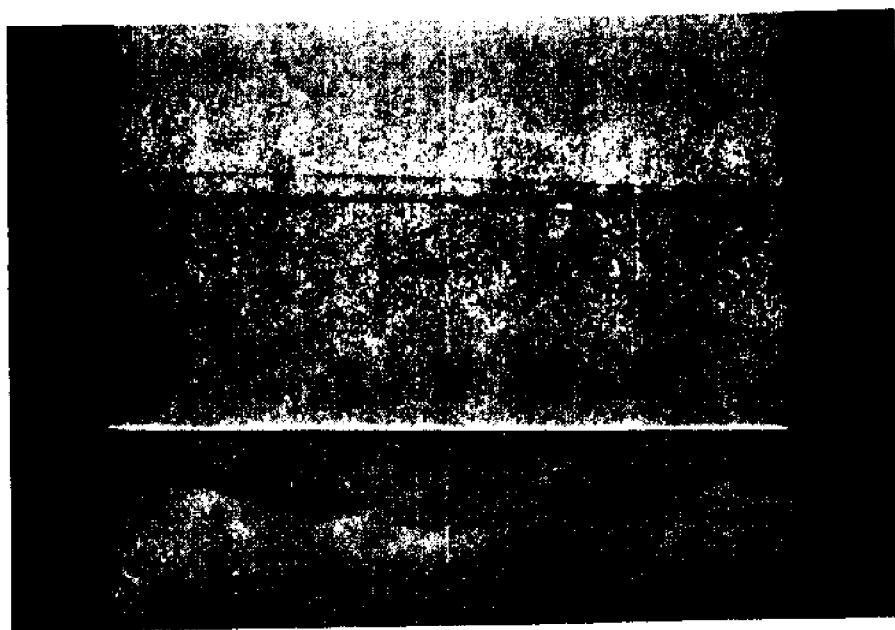


Figure 2. Thin-layer chromatogram illustrating the sensitivity of the proposed procedure in detecting the given condensed phosphates.

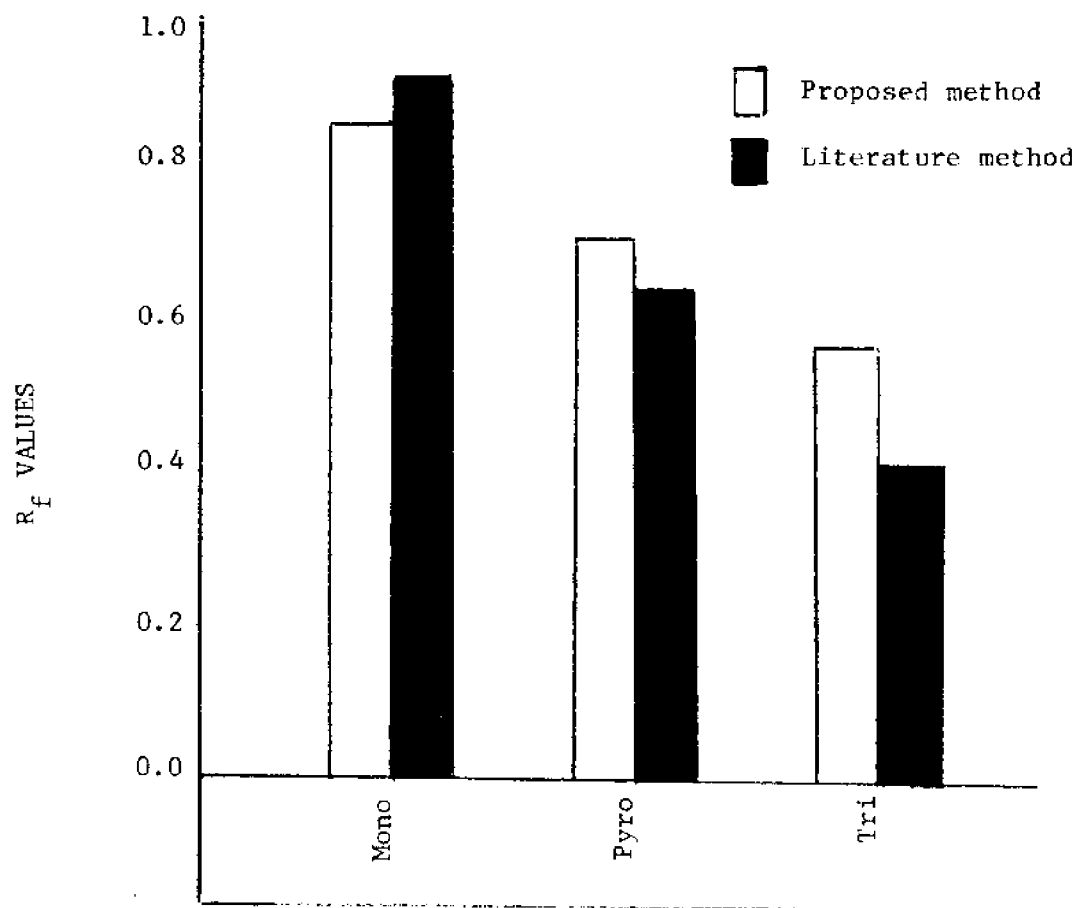


Figure 3. Distribution of R_f values for condensed phosphates in STP treated shrimp during frozen storage.

in treated shrimp was studied during several weeks of frozen storage. Extracted shrimp samples were once analyzed before freezing and again at weekly intervals throughout the storage period. Although triphosphates were detectable through 6 weeks of frozen storage in STP treated shrimp, the color development for the 6-week sample was relatively lighter. By contrast, the color development for the monophosphate spot was relatively darker. This indicates that the distinct hydrolysis of sodium triphosphate in treated shrimp will occur sometime after 5 weeks of frozen storage. However, R_f values for the extracted shrimp samples during frozen storage remained unchanged from those obtained on standard plates (Figure 3).

Thin-layer spots were quantitatively analyzed for phosphates by using a technique suggested by Crowther in 1955 for paper chromatography. Results obtained on analyzing mixtures of mono-, pyro-, and triphosphates are given in Table 2. Complete hydrolysis of tri and pyrophosphates is essential for obtaining satisfactory rates of recovery.

Table 2. Analysis of Mono-, Pyro-, and Triphosphate mixtures

MIXTURE TYPE	COMPOSITION (% added)	MEASURED (% found)	DIFFERENCE
1. Mono	10.0	10.0, 10.0	0.0, 0.0
Pyro	10.0	8.6, 8.4	-1.4, -1.6
Tri	80.0	80.3, 80.5	+0.3, +0.5
2. Mono	10.0	10.0, 10.0	0.0, 0.0
Pyro	20.0	18.6, 18.2	-1.4, -1.8
Tri	70.0	70.4, 70.1	+0.4, +0.1
3. Mono	10.0	10.0, 10.0	0.0, 0.0
Pyro	30.0	28.4, 28.0	-1.6, -2.0
Tri	60.0	60.3, 60.6	+0.3, +0.6
4. Mono	10.0	10.0, 10.0	0.0, 0.0
Pyro	40.0	38.8, 38.0	-1.2, -2.0
Tri	50.0	50.1, 50.4	+0.1, +0.4

CONCLUSION

Recommended procedure is simple and can be used for rapid detection (0.5 hrs vs. 2.5 hrs required for the development of TLC plate by using the other method) of condensed phosphates without sacrificing the quality of separation. Because of its high sensitivity towards detection the technique can be applied to determine whether or not a fish has been treated with polyphosphates. Standard condensed phosphate mixtures were

analyzed quantitatively and individual phosphates were recovered satisfactorily. This information is essential in order to determine the extent of hydrolysis of condensed phosphates in treated shrimp during prolonged frozen storage.

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QUALITY ASSESSMENTS IN PRODUCTION AND PROCESSING OF CALICO SCALLOPS (*Argopecten gibbus*)

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INTRODUCTION

The development of the calico scallop (*Argopecten gibbus*) fishery in the Gulf and South Atlantic region of the United States has been adequately reviewed in previous publications (1-6) and fishery management documents (7). Compared to the established regional fisheries for shrimp, blue crab, and certain traditional fish, calico scallop production is relatively a new emerging fishery. Although landings have been recorded since 1959 (2,8-9), production was sporadic until the 1970's and has significantly increased since 1981 (Figure 1). Overall this industry has evolved 24 years from the initial processing, but in terms of current production rates and volumes per plant this industry is less than 10 years old.

A consequence of this rapid growth has been many newcomers to both regulations and operations of calico scallop production, as well as more intense market competition. In some instances product quality has suffered. Pertinent State and Federal regulatory agencies have received complaints on product decomposition, presence of parasites, and mislabeling (confusing Bay and Calico scallops). Quality has been identified as the most important attribute to assure the economic welfare of this relatively new fishery. Although specific studies for calico scallop production in North Carolina and informal guidelines issued by the National Marine Fisheries Service have provided useful quality control manuals (10-11), this work is not current with the present mode and volume of calico scallop production. During the 1970's the major production of calico scallops shifted to the eastern coast of Florida. In the last 4 years annual production has increased 5 to 8 fold and shucking capability has been adjusted to handle higher count scallops. There are no published guidelines for quality control during harvest, especially in the warmer, subtropical climates. In particular, there are no guidelines to address parasite problems. Thus, current regulatory and industry concerns for quality control in calico scallop production require further investigation. This report

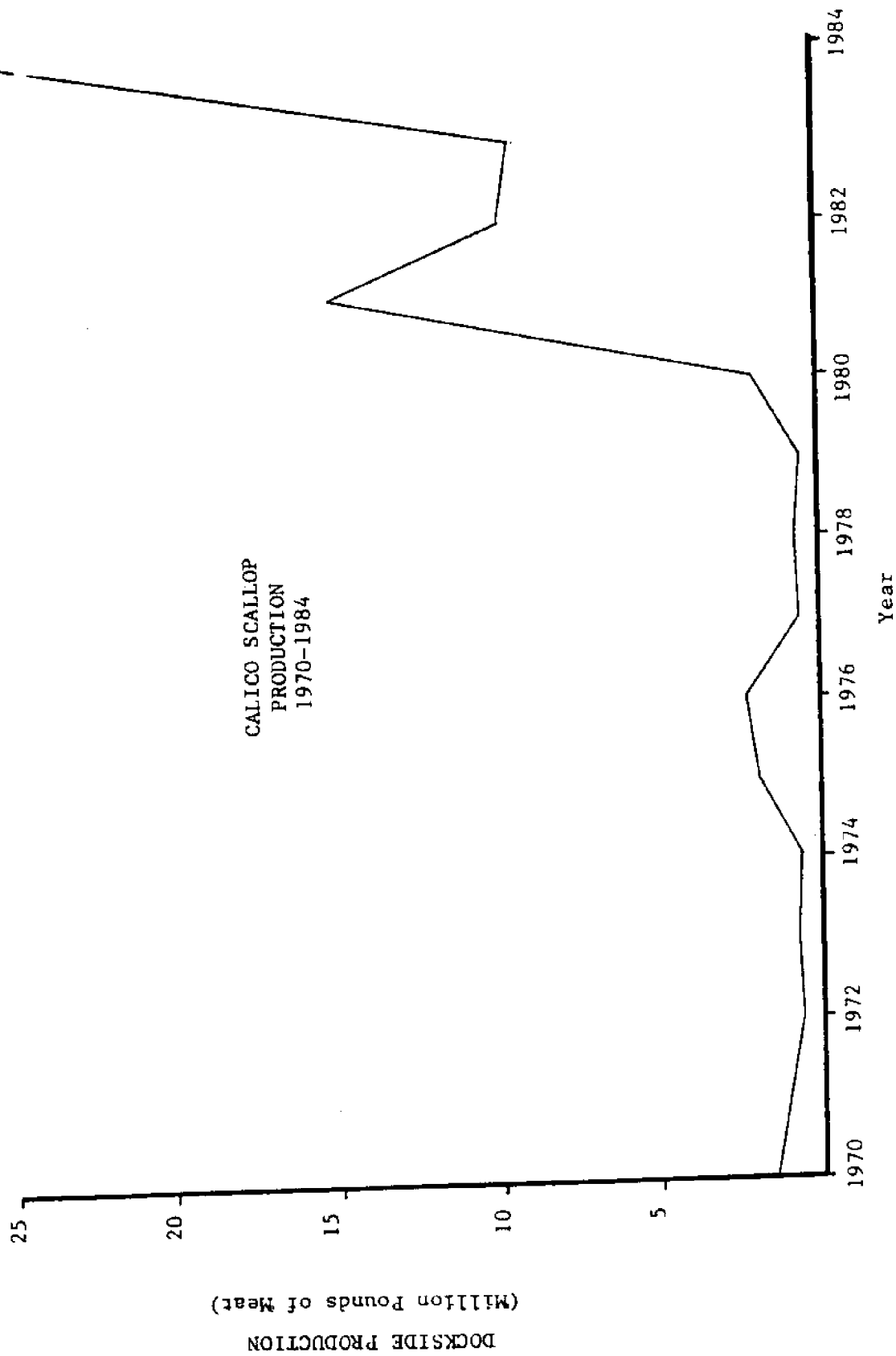


Figure 1. Production of calico scallops during the last decade. (Source: National Marine Fisheries Service Fisheries of the United States, from Current Fishery Statistics reports in 1971 through 1983 and preliminary supplements from U.S. Department Commerce, National Fisheries Service Statistical Branch - Miami).

includes the microbiological portion of the recent quality assessment work (12) conducted to address these concerns. This text (12) should be referenced for further details on harvest, processing and storage of calico scallops.

METHODS

The basic study approach was to provide a microbial description of calico scallop production from actual harvest and processing. Sampling for microbial analyses was conducted simultaneously from the same batches (same vessel or harvest as landed and processed). The results per month can be compared relative to the same vessel and firms sampled. Actual field work on the vessels and in the processing plants occurred during October 1983 through August 1984 to assure a continuous assessment through seasons. All data is based on the established 1983-84 production in Port Canaveral, Florida.

Samples for microbial analyses were taken from the predetermined processing points (Figure 2). Hand-shucked samples from shellstock on the vessel and at the dockside included the meats (whole adductor muscle) with attached viscera. Samples after steam shucking were analyzed with remaining viscera attached, but all further processing samples only included meats. Samples (20-30g) prepared on the vessel or in the plant were placed in Whirl-pak bags and massaged for 60 seconds with sterile Butterfield's diluent (30 ml) then plated for aerobic plate counts at 20 to 25°C. Parallel and additional microbial analyses were conducted within 12 hours of collection. These latter samples (25g) were blended with sterile Butterfield's diluent (225 ml) for further analyses. All further analyses conformed to the Bacteriological Analytical Manual for Foods, BAM (13) with the exception of the surface plating technique for Aerobic Plate Counts (APC) with incubations at 35°C for 48 hours, 20°C for 5 days and 7°C for 10 days. In addition, the plate count agar was supplemented with 0.5% NaCl.

All samples were also examined for Salmonella and Staphylococcus (14). Vibrio sp. were determined in October and June sampling using the MPN protocol. Vibrio sp. were determined by transferring 1 ml aliquots of the sample homogenate into tubes of alkaline peptone water (1% peptone, pH 8.4) to obtain a 3-tube MPN series. After incubation for 8 to 10 hours at 37°C, positive or turbid alkaline peptone tubes were streaked onto TCBS agar (Difco) plates for isolation of colonies. TCBS agar plates were incubated for 24 hours at 37°C and morphologically typical colonies of Vibrio sp. were isolated and identified using standard biochemical tests and API-20E biochemical test strips (Analytab Products, Plainview, NY).

Processing (Sampling) Points:

1. Shellstock from dockside
2. Steam shucked meats and water
3. Eviscerated meats
4. Meats and water from chill tank

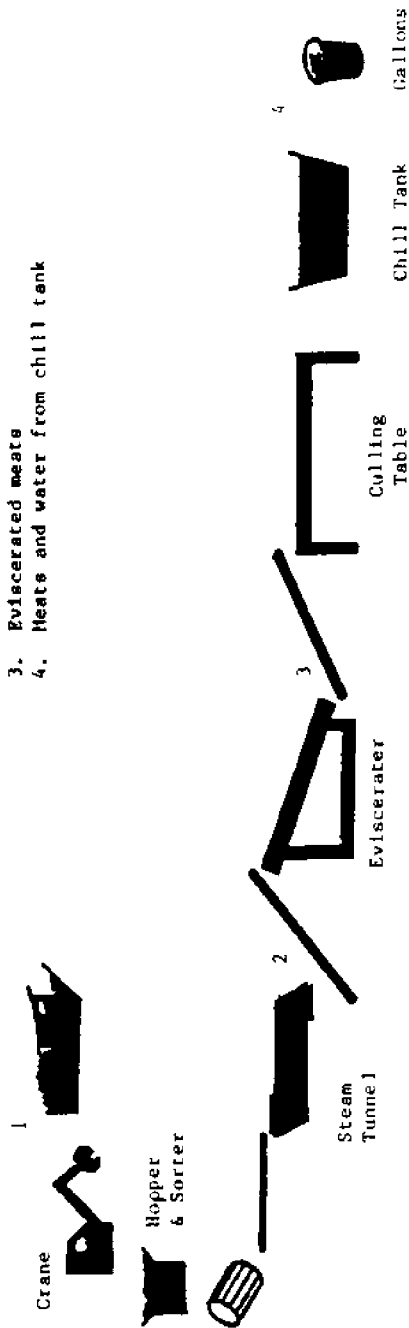


Figure 2. Illustration of processing operations and processing points used for sampling throughout the study.

RESULTS AND DISCUSSION

HARVEST

Harvest of calico scallops involved bottom trawls pulled across established beds primarily located along the central east coast of Florida. The catch is unloaded on the deck. Total time for scallops on the deck can range from 12 to 18 hours. During October, February and June this storage time on deck did not cause excessive thermal abuse (Table 1) and the catch, from top to bottom of the compiled harvest, remained alive or showed no sensory signs of initial spoilage. This was true for samples which had been exposed to 78-81.5°F (25.6-27.5°C) deck temperatures for 13 hours. Microbial results support the observed product conditions, but indicate vessel product abuse can occur (Table 2). In general the landed product can be expected to contain 10^3 to 10^4 microorganisms/gram (APC, 20°C) of meats and viscera. There was no discernible distribution of bacterial counts relative position of the scallop samples in the pile of scallops harvested. In two instances the dockside microbial loads exceeded 10^5 microorganisms/gram (APC, 20°C) with corresponding high counts at 7°C incubation indicative of psychrotropic spoilage bacteria. One situation was traced to a vessel breakdown during a major rainstorm, the other was thought to result from dockside washing of the catch with water pumped from the port. In these conditions no immediate adverse sensory attributes were noted.

PROCESSING

Processing generally elevated the microbial counts (APC) as compared to dockside counts (Table 3). The increases do not denote any major problems and reflect similar situations common in most seafood processing operations. The monthly results tend to reflect higher consistent counts at processing points during June, but the variable counts at 7°C were thought to be related to vessel conditions, duration of harvest, and/or operation of the chill tank.

In comparison, the dockside counts indicate the mechanical-steam shucking process elevates the mean APC's (35, 20, 7°C) approximately 10 fold higher than on dockside product (the monthly results in Table 3 correspond with the respective dockside results in Table 2). Although the shucking process utilized pressurized steam in tunnels or tanks, the actual temperature of the scallop meat should remain below 140°F (60°C). Higher temperatures would be evidenced by a cooked or partially cooked appearance on the surface of the meats. This

Table 1. Temperatures within a typical deck load of calico scallops accumulated during a daily harvest. Temperatures were continuously recorded from wire probes placed throughout the catch piled on the deck. Temperature readings in the pile are averaged for three probes per depth.

<u>Ambient Conditions</u>	<u>Location of thermal probe (feet above deck)</u>	<u>Temperature(°F)</u>		<u>Duration (hours)</u>
		<u>Initial</u>	<u>Final</u>	
October:	Top (> 6')	78.6	78.4	5.5
Air (76-82°F)	Middle (2-4')	78.0	81.0	9.5
Water (75°F)*	Bottom (0')	78.0	81.5	13.0
February:	Top	70.0	70.0	3.0
Air (70-75°F)	Middle	70.5	70.2	9.0
Water (72°F)*	Bottom	71.5	71.3	12.0
June:	Top	77.4	77.3	5.0
Air (85-88°F)	Middle	76.2	79.8	12.0
Water (79°F)*	Bottom	76.2	79.3	14.0

*Surface water temperature at harvest.

Table 2. Microbial analyses (APC-aerobic plate counts, microorganisms/gram) for whole scallops, meat and viscera taken immediately from the water and after deck storage and unloading at the dock. APC's (25°C) represent analyses run at sampling location, while other analysis (35°, 20°, and 7°C) were conducted in the lab. Counts listed represent geometric means for at least three samples.

Month	Vessels*	IMMEDIATE HARVEST					LANDED DOCKSIDE			
		APC, °C					°C			
		35°	25°	20°	7°		35°	25°	20°	7°
Oct.	A t		2.0X10 ²				1.3X10 ³	3.9X10 ²	1.5X10 ³	(2.7X10 ¹)**2
	m		2.8X10 ²				1.3X10 ²	6.2X10 ²	5.4X10 ²	(1.0X10 ¹)
	b		1.0X10 ²				1.8X10 ⁴	5.4X10 ³	1.9X10 ⁴	(1.0X10 ¹)
Nov.	B						4.2X10 ³		2.4X10 ³	4.0X10 ¹
	C						3.8X10 ³		6.3X10 ³	4.9X10 ²
	D						7.7X10 ³		5.2X10 ⁴	(1.0X10 ⁰)
	E						3.2X10 ³		5.5X10 ³	(2.8X10 ⁰)
	F						3.6X10 ³		6.7X10 ³	(9.1X10 ¹)
Dec.	G						1.1X10 ⁵		1.6X10 ⁵	1.0X10 ⁴
Feb.	G t	1.0X10 ²	2.7X10 ³	1.4X10 ³	1.1X10 ³		1.1X10 ³	2.4X10 ³	8.0X10 ³	2.9X10 ³
	m	1.5X10 ²	1.7X10 ³	1.4X10 ³	3.8X10 ³					
	b	2.2X10 ²	1.4X10 ³	2.5X10 ³	7.1X10 ²		3.0X10 ⁴	3.0X10 ⁴	1.1X10 ⁵	6.6X10 ⁴
Jun.	I t		1.0X10 ³				1.1X10 ³	1.0X10 ⁴	1.8X10 ³	1.9X10 ²
	b		1.3X10 ³				4.8X10 ³	6.2X10 ⁴	7.0X10 ⁴	2.3X10 ³

* Different vessels are denoted by capital letters. The smaller case letters, t, m, and b denote sample locations within an accumulated catch of scallops (i.e., top, middle and bottom of the compiled catch, respectively).

** Counts listed in parenthesis denote estimates per gram.

Table 3. Aerobic plate counts (microbial organisms/gram) for calico scallop meats sampled during processing. The listed geometric means represent three to six samples depending on month, and all samples per month came from one vessel through processing.

		Aerobic Plate Counts (°C)			
Month	*Firms Unidentified	Process	35°	20°	7°
-----organisms/gram-----					
Oct.	I	MS	1.4X10 ⁵	1.4X10 ⁵	(1.5X10 ²)
		E	7.9X10 ⁴	7.1X10 ⁴	5.8X10 ²
		CT	3.2X10 ⁵	4.0X10 ⁵	1.2X10 ⁵
Nov.**	II	MS	4.5X10 ⁶	2.8X10 ⁶	1.1X10 ⁶
		E	2.8X10 ⁵	3.0X10 ⁵	1.0X10 ²
		MC	5.3X10 ⁵	4.2X10 ⁵	6.0X10 ³
	III	MS	3.7X10 ³	3.2X10 ³	(3.8X10 ¹)
		E	1.8X10 ³	1.5X10 ³	(2.5X10 ¹)
		CT	1.2X10 ⁴	1.1X10 ⁴	(2.3X10 ²)
Dec.	IV	MS	1.0X10 ⁵	9.4X10 ⁴	2.8X10 ³
		E	6.0X10 ⁴	5.7X10 ⁴	6.0X10 ³
		CT	1.0X10 ⁴	1.3X10 ⁵	1.3X10 ⁴
Feb.	V	CT	6.5X10 ⁵	3.6X10 ⁵	3.8X10 ⁵
Mar.	VI	CT+1 day	9.5X10 ⁴	9.0X10 ⁴	2.1X10 ⁴
Jun.***	VII	MS	4.8X10 ⁵	8.0X10 ⁴	2.8X10 ⁴
		E	3.8X10 ⁵	3.4X10 ⁵	5.3X10 ³
		CT	3.0X10 ⁵	3.8X10 ⁵	5.3X10 ³
Aug.	VIII	CT+1 day	4.7X10 ⁴	6.2X10 ⁴	6.2X10 ²

* Three firms were assessed, each at least twice. Letters, MS, E, and CT denote samples taken after mechanical shucking, evisceration, and soak in chill tank, respectively.

** November data represents means across four separate vessels landing product consecutively (see Table 4).

*** June data represents means for two sets of samples taken as a vessel was initially (top) and finally (bottom) unloaded and processed (see Table 5).

meat temperature in combination with post-shuck flume temperature of 90-125°F (32-53°C) would promote some bacterial growth. Likewise, the construction and operation of the shuckers warrants further attention for periodic clean-up to prevent bacterial accumulation about the tunnels which may contaminate scallop meats.

Bacterial counts tend to decrease during evisceration due to the rinsing and dilution influence of the high pressure water sprays which cleanse and 'lubricate' the eviscerator rollers. Decreasing the temperature of the sprays could impart some advantages.

Although the chill tank could decrease the eviscerated product temperature from 78-79°F (25.5-26.1°C) to 38-40°F (3.3-4.4°C), the water in the tanks generally 'innoculated' the meats prior to packaging. In one instance when tank water temperature was at 53°F, APC's (7°C) on the scallop meats increased 200 fold after the brief soak (1 to 2 minutes) in the chill tank. Interestingly, there was no apparent influence of processing time or amount of consecutively processed product on the bacterial counts of finished scallops encountered during one month of split sampling. Samples taken for bacterial analyses at the beginning (top) and end (bottom) of processing one vessel's catch in June generally yielded similar results (Table 4). However, for scallops emerging from the mechanical shucker, samples taken at the beginning (top) had higher counts (40-100 fold) than those taken at the end (bottom) of processing per vessel indicating a decrease of bacterial contamination via the shucker and/or shucker flume water as processing progressed. Apparently, down time between processing catches from individual vessels allows bacterial growth within the line of shucking equipment and associated flume waters. There was no discernible pattern in bacterial analyses for samples taken during four consecutively processed catches (Table 5). No routine clean-up or altered procedures occurred between processing each vessel's catch. Thus the processing mode and methods were operating with an established bacterial load for the operating conditions.

Microbial analyses indicate the chill tank waters and shucking process and/or flume water from the shucker are a probable source of fecal coliform and *E. coli* contamination (Table 6). Although fecal coliforms and *E. coli* were recovered sporadically on dockside handshucked meats these organisms could proliferate slightly during processing and provide a source for accumulation on equipment in the processing operation. The presence of psychrotrophic (APC, 7°C) as well as coliform bacteria in the chill tank could have an impact on the subsequent quality and refrigerated shelf-life of the

Table 4. Aerobic plate counts (microorganisms/grams of meat or ml of water) for calico scallop samples taken at dockside through processing for one vessel unloaded in June. Samples were taken at the beginning (top of the harvest or last caught) and end (bottom of the harvest or first caught) of the unloading and processing operations. Listed geometric means represent three samples

Sample Location		Aerobic Plate Counts (°C)			
		35°	25°	20°	7°
Dockside	top	1.1X10 ³	1.0X10 ⁴	1.8X10 ³	1.9X10 ²
Shellstock	bottom	4.8X10 ⁴	6.2X10 ⁴	7.0X10 ⁴	2.3X10 ³
Mech.	top	9.8X10 ⁵	-----	1.4X10 ⁶	5.4X10 ⁴
Shucked	bottom	1.8X10 ⁴	-----	1.8X10 ⁴	1.3X10 ³
Eviscer.	top	4.9X10 ⁵	-----	4.4X10 ⁵	3.0X10 ⁴
	bottom	2.6X10 ⁵	-----	2.4X10 ⁵	2.8X10 ⁴
Chill	top	3.1X10 ⁵	-----	3.7X10 ⁵	6.5X10 ³
Tank	bottom	3.0X10 ⁵	-----	3.9X10 ⁵	4.2X10 ³
Chill	top	9.4X10 ⁵	-----	7.9X10 ⁵	1.5X10 ⁴
Tank Water	bottom	7.9X10 ⁵	-----	1.0X10 ⁶	1.0X10 ⁴
Shucker	top and	1.8X10 ⁵	---	1.4X10 ⁵	3.5X10 ³
Flume Water	bottom				

Table 5. Aerobic plate counts (microorganisms/gram of meats or ml of water) for calico scallop samples and chill tank water taken during the unloading and processing of four separate vessels handled consecutively at one processing firm in November. The listed geometric means represent three samples.

Sample Location	Vessel	Aerobic Plate Counts (°C)		
		35°	20°	7°
Dockside	1	3.7×10^3	6.3×10^3	3.9×10^2
Shellstock	2	7.7×10^3	5.2×10^4	1.0×10^0
	3	3.2×10^3	5.5×10^4	2.8×10^0
	4	3.6×10^3	6.7×10^3	9.1×10^1
Mechanically Shucked	1	2.9×10^4	2.3×10^4	1.5×10^2
	2	2.6×10^3	2.1×10^3	1.0×10^1
	3	1.8×10^3	2.0×10^3	1.0×10^1
	4	2.1×10^3	1.7×10^3	9.3×10^1
Eviscerated	1	6.1×10^3	3.3×10^3	1.5×10^2
	2	3.5×10^3	2.1×10^3	1.0×10^1
	3	9.1×10^2	2.0×10^3	1.0×10^1
	4	1.3×10^3	1.5×10^3	2.2×10^1
Chill Tank	1	1.5×10^4	1.4×10^4	7.8×10^2
	2	1.1×10^4	1.1×10^4	3.0×10^2
	3	1.0×10^4	1.4×10^4	1.0×10^2
	4	1.2×10^4	7.9×10^3	2.2×10^2
Chill Tank Water	1	7.0×10^2	1.1×10^2	5.4×10^0
	2	1.3×10^5	1.1×10^5	2.0×10^3
	3	1.1×10^5	8.0×10^4	2.0×10^3
	4	1.4×10^5	9.4×10^4	2.8×10^3

Table 6: Summary of fecal coliform (FC) and *E. coli* (EC) data (units: MPN's/g meats of MPN's/ml water) taken for scallops processed from one vessel per month. Values for processed scallop meats and dockside meats plus viscera represent the geometric mean for at least three samples. Number of samples for geometric means for water samples are identified in parenthesis.

Sample Location	Results/Month, 1983-84											
	Oct.		Nov.		Dec.		Feb.		Jun.			
	(A)*		(B)**		(C)		(D)		(E)		(F)	
	FC	EC	FC	EC	FC	EC	FC	EC	FC	EC	FC	EC
Dockside	4.5	NR										
Vessel: t***	1.5	NR	NR	NR	3.6	3.6	1.9	1.9	NR	NR	NR	NR
m 1.5	NR						NR		NR	1.9	1.5	
b NR	NR						NR		NR			
After Shuck	2.1	2.1	NR	NR	>1100	>1100	230	230			2.3	2.3
After Evisc.	NR	NR	NR	NR	3.6	3.6	11	11			NR	NR
Chill Tank	10.0	4.4	NR	NR	NR	NR	38	38	NR	NR	NR	NR
Chill Tank Water	40	2.5	NR	NR	2.3	2.3	4.3	3.4			t7.5	0.4
	(3)		(4)		(1)		(4)				b9.3	NR
											(1)	
Flume Water from Shucker							>110	>110			9.3	9.3
							(1)				(1)	

*Letters (A) thru (F) denote unidentified, individual scallop firms. Three firms were involved.

**November data (B) represent means for samples from 4 separate vessels unloaded consecutively.

***Small letters t, m, and b denote top, middle and bottom samples from same vessel.

scallops. Additional efforts are needed to reduce their accumulation. More frequent (6 hours) drainage and proper cleaning of the chill tanks should be encouraged, and additional insulation and refrigeration should be considered to maintain lower operating temperature. As previously mentioned, attention could be given to cleaning shuckers and associated plumbing including flume water to prevent bacterial accumulation. The high temperatures in this equipment would provide a selective environment for growth and/or accumulation of coliform bacteria.

The persistence of fecal coliforms and E. coli on meats and in processing waters was unanticipated. The only identified source was the incoming raw materials. Careful evaluations eliminated the water supply as a probable source in one plant. Obvious cross-contamination with sewage was not evident, but detailed bacterial assessments would be necessary to rule out any possible hidden leaks, siphons, etc. Warm, damp and improperly sanitized conditions appeared to enhance proliferation on the product as well as in the processing effluents and/or fluming waters. Realizing the product is initially harvested essentially free of fecal coliforms or fecal contamination, from deep (10-15 fathom) ocean waters (3.4-3.5% salt), the presence of fecal coliforms and E. coli in processed scallops warrants thorough sanitation procedures in the plant and on the vessels before and after harvest. In-line chlorination for processing and/or flume waters, frequent and proper cleaning/sanitizing procedures, and generally improved manufacturing practices should diminish coliform and E. coli counts on the facilities and product.

Overall the microbial assessments have not indicated any major concerns detrimental to product quality or safety during scallop processing. No Staphylococcus aureus nor Salmonella have been recovered from any processing point (Figure 2) during any month of sampling. Vibrio sp. analyses run on a full complement of samples in October, and on dockside and chill tank samples in June recovered no V. parahaemolyticus, V. cholera, or V. vulnificus.

CONCLUSION

Calico scallop processing generally elevated the microbial counts (APC's) on meats by approximately 10 fold higher than on dockside product. Processed calico scallops had an immediate bacterial load (APC's, 20°C) of approximately 10^4 to 10^5 microorganisms/gram of meats. There was no apparent influence of processing time per vessel or amount of consecutively processed product on the bacterial counts of finished scallops. The processing mode and methods appear to be functioning with

an established bacterial load for the operating conditions. Chill tank waters and the shucking process and/or flume waters from the shucker are a probable area for fecal coliforms and E. coli contamination. Any original source was not detected in the plants, but occasionally occurrence was noted on the deck loaded harvest prior to processing. No Staphylococcus aureus, Salmonella, or Vibrio (parahaemolyticus, cholera, or vulnificus) were recovered from any processing points.

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THE EFFECTS OF BRINE FREEZING CRAWFISH

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INTRODUCTION

Interest in commercial farming of crawfish has increased in recent years due to improvements in technology and increased demand but the industry has thus far been limited to a "live product". The Marine Advisory Service of Texas with the Seafood Technology Department of Texas A&M University (Dr. Gunnar Finne), The Texas Agricultural Extension Service (Mr. Don Kachtik and Dr. Jim Davis), Applied Microbiological Services (Dr. Ranzell Nickelson II) and the Crawfish Farmers Association of Texas were interested in seeing what effects brine freezing would have on crawfish. In addition, taste comparisons between brine frozen crawfish and fresh crawfish from the same crop were made. To do this a trained taste panel consisting of 10 panelists was used. Comparisons of fresh purged to fresh unpurged crawfish were made and taste changes, chemical changes, total bacterial changes, aromatic changes and texture changes were monitored for purged and unpurged, brine frozen crawfish. This study has been underway for seven months and is continuing, but the preliminary results are presented at this time. Brine freezing appears to offer the potential for extending the crawfish market.

The use of salt brine for refrigerants and fish curing is common in the seafood industry, but has not been widely used for crawfish. A brine solution provides a method for rapid freezing and by adding corn syrup or molasses to the mixture, a glaze is formed on dipped whole crawfish which acts to prevent dehydration, helps maintain texture, and prevents oxidation (rancidity).

Quality freezing and success are no accident, but are instead due to paying close attention to procedure and understanding the theories involved in the freezing process.

If the brine in the tank is of the correct salt concentration and is adequately precooled, the crawfish will freeze quickly and will not absorb high quantities (1.5% or higher) of salt.

The salt concentration of the brine tank is critical for proper freezing of crawfish. The freezing point of the water can be lowered predictably with a given salt concentration. The optimum temperature that is reached with a brine solution is -6°F or -21°C . This is with a salt concentration of 23.3% by weight, and is called the eutectic point. Any concentration above or below will produce higher temperatures (see Figure 1).

Also maintenance of a stable non-fluctuating hold temperature is important for crawfish. The ideal hold temperature which strongly retards biochemical changes in frozen crawfish is -20°C . Temperatures in cold storage should not be allowed to fluctuate any more than 10°C , otherwise a significant loss of quality may be detected.

Corn syrup or molasses is added to the brine solution at 0.12 gallons of syrup per gallon of water or 1.19 pounds (dry form) per gallon of water. This provides a flexible ice-syrup glaze around the crawfish. Table sugar is not recommended as a glaze compound because it produces a brittle coating which tends to chip or break when the crawfish are handled, especially when net or potato sacks are moved.

If crawfish are allowed to freeze slowly, large ice crystals will grow within each individual muscle cell and eventually puncture the cell walls. Rapid freezing will allow only small ice crystals to develop within cells. The small crystals will not puncture as many cell walls and the moisture loss will be minimal when crawfish are thawed. If thawing is necessary then rapid thawing of brine frozen crawfish is recommended by using cool running water but the best method to use if the crawfish are to be boiled is to place the frozen, whole crawfish directly into boiling water. Once the water begins to boil again, crawfish are allowed to cook for 4 minutes before removing.

METHODS AND MATERIALS

One hundred pounds of live crawfish were acquired from the Dan Harris Farm and transported to College Station (50 pounds of purged and 50 pounds of unpurged crawfish).

A brine freezing unit was constructed, consisting of two 32 quart IGLOO coolers. The cooling coil of a BLUE M cooling unit was submerged in the brine solution (23.3% salt-by weight) of one cooler and the other cooler was used to brine dip and freeze the crawfish. The two coolers were interconnected at the drain and a small pump circulated the brine solution from one cooler to the other. Preparation of the brine freezing solution followed the procedures outlined by Hilderbrand (1973).

Crawfish were separated into 2 size groups (small and medium to large) and were placed into 5 pound potato sacks, which held approximately 3 pounds of crawfish in each.

A LEEDS & NORTHRUP temperature probe was placed in the middle of the sack and another probe was placed within the tail muscle of one crawfish. The bag was then placed into the brine solution. When the temperature of the tail muscle reached that of the brine solution, the sack was removed. This process was timed for both sizes of crawfish. After freezing, one half of the crawfish were placed into a SO-LOW-UE800 chest type freezer and the remaining crawfish were held in a FRIGITEMP walk-in freezer (both at -20°C).

Another group of crawfish ($\frac{1}{2}$ purged, $\frac{1}{2}$ unpurged) was held alive in a FRIGITEMP walk-in cooler for taste test comparisons. Taste panel or sensory panel testing was conducted initially with fresh crawfish and monthly with brine frozen crawfish using sensory panel methods outlined in the Guidelines for the Selection and Training of Sensory Panel Members (1981) and The Manual on Sensory Testing Methods (1968), both published by the American Society for Testing and Materials (Library of Congress Catalog Numbers: 81-68431 and 68-15545, respectively). Two taste tests were used, the triangle test and the nine-point hedonic test, both commonly used for sensory panel testing. The triangle test (Figure 2) was used to detect differences or likenesses in crawfish (purged vs. unpurged; frozen vs. fresh etc.). The nine-point hedonic test (Figure 3) was administered to panelist monthly using brine frozen crawfish to detect any change which may have occurred in cold storage.

In addition to taste panel tests monthly, crawfish were tested for total bacterial counts using standard aerobic plate count techniques. Twenty grams of purged crawfish tail muscle (10 grams each replicate) and 20 grams of unpurged crawfish tail muscle (10 grams each replicate) were used monthly for these tests.

Chemical changes in frozen crawfish were monitored by using 10 grams of purged and 10 grams of unpurged crawfish tail muscle monthly. The direct thiobarbituric acid extraction method for determining oxidative rancidity was used. This is a test to detect lipid oxidation or the build-up of aldehydes in frozen storage (see Vyncke 1976).

Crawfish used for taste tests were removed from the freezer and immediately placed into boiling distilled water. Whole crawfish were left in the water for 4 minutes after it began to boil again. No seasoning was added. Animals were tailed and tails were peeled before presenting them to taste panelists.

RESULTS AND DISCUSSION

The time required to freeze a 3 pound sack of medium to large crawfish in a -10°C or 14°F brine tank was 25.5 minutes (see Figure 4). The time to freeze a 3 pound sack of small crawfish was 13.3 minutes (see Figure 5).

Frozen crawfish are very brittle and appendage damage may occur when sacks are moved or too much weight is placed on top of the sacks. Placing sacks of frozen crawfish into a box helps alleviate this problem when moving the sacks is necessary.

The results of aerobic plate count tests can be seen in Table 1 and in Figure 6. Plate counts indicate the total number of bacteria in both fresh whole and frozen crawfish tail muscle differ considerably as might be expected. The difference between fresh, whole, purged crawfish and fresh, whole, unpurged crawfish can be seen in Table 1 and in Figure 6. One can see frozen tail muscle bacterial counts are much lower than fresh whole crawfish bacterial counts and that there is a difference in frozen tail muscle, purged and unpurged bacterial counts, at least through the third month in cold storage. After that time, they are very similar in numbers. Whether these differences in APC's during the first 3 months are significant is yet to be determined. Statistical analyses will be conducted when sensory evaluations are terminated. The rise of APC's in cold storage cannot be explained but contamination sources were checked and verification tests were conducted resulting in similar APC's.

Table 1. Aerobic plate counts of Brine Frozen Crawfish

	MONTH # in storage (-20°C)	APC at 25°C for 24 hours	
		PURGED # Bacteria/g	UNPURGED # Bacteria/g
Fresh Whole	0	1.25×10^7	2.0×10^7
Frozen			
Tail Muscle Only	0	1.2×10^4	1.4×10^5
	1	1.2×10^4	1.4×10^5
	2	1.2×10^4	1.6×10^6
	3	9.0×10^4	1.3×10^5
	4	1.5×10^5	9.0×10^5
	5	1.8×10^5	1.8×10^5
	6	8.0×10^5	9.0×10^5
	7	5.6×10^6	4.5×10^6

The results of TBA tests indicated also that there is a slight difference in purged and unpurged frozen tail muscle throughout the entire sampling period. (See Table 2 and Figure 7). TBA's are expressed in mg/kg. Three (3.0) mg/kg TBA is considered spoiled or rancid. There is generally no human taste detection until TBA's reach the 1.5 mg/kg range. Crawfish tail muscle is approaching this range after 7 months in cold storage. Several panelists have only recently noted an "after taste" but as a whole the panelists have not noted obvious "off-flavors".

Table 2. TBA values for Brine Frozen Crawfish

MONTH #	TBA's mg/kg	
	PURGED	UNPURGED
1	0.58	0.63
2	0.60	0.68
3	0.81	0.82
4	0.90	0.95
5	1.0	1.2
6	1.2	1.4
7	1.54	1.64

(No human sensory detection likely until 1.5 mg/kg)

Results of taste panel tests indicate that there are detectable differences in the taste between individual crawfish. These individual differences could possibly be attributed to the environment in which they were grown or the molt cycle which each was in or could be attributed to the feed which each had been consuming before capture. The use of seasoning during cooking is generally enough to mask these individual taste differences.

Additional results indicate that there are detectable differences in fresh, purged crawfish and frozen, purged crawfish from the same crop. Eighty-six percent of the panelists did detect a difference in taste. A surprising result was that 43% of those panelists who detected a difference between fresh and frozen crawfish preferred the frozen because of a milder taste, a saltier taste, or what was described as a nuttier taste.

Sensory panel tests also indicated that 43% of the taste panelists did detect a difference in taste between fresh, purged crawfish tail muscle and fresh, unpurged crawfish tail muscle; whereas, 57% of the panelists did not detect any differences in taste, aroma, texture etc.

Other than appendage breakage there were no side-effects associated with brine freezing at -10°C . Appendage breakage can be kept to a minimum if the crawfish brine sacks are placed into protective boxes after freezing and sacks are not stacked on top of each other.

Statistical tests will be required before analyses and interpretation of all test results are complete. Other tests will also be conducted on frozen crawfish before this study is terminated, such as protein denaturation (or total proteolytic enzyme activity) and sodium chloride content. Tests comparing fresh, cooked crawfish

to cooked, brine frozen crawfish (after 1 year in cold storage) might produce some interesting results. Perhaps a better direction for future studies is to compare a larger number of quality factors at various intervals during cold storage and more importantly conduct studies to standardize the brine freezing process for crawfish.

From the preliminary results obtained in this very limited study, brine freezing appears to be a viable method of extending the crawfish market.

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2. Vyncke, W., 1976. Evaluation of the direct thiobarbituric acid extraction method for determining oxidative rancidity in Mackerel (*Scomber scombrus* L). Seifen-Anstrichmittel 77:239-240.

Figure 1 - Effect of NaCl concentration on freezing point of brine solution.

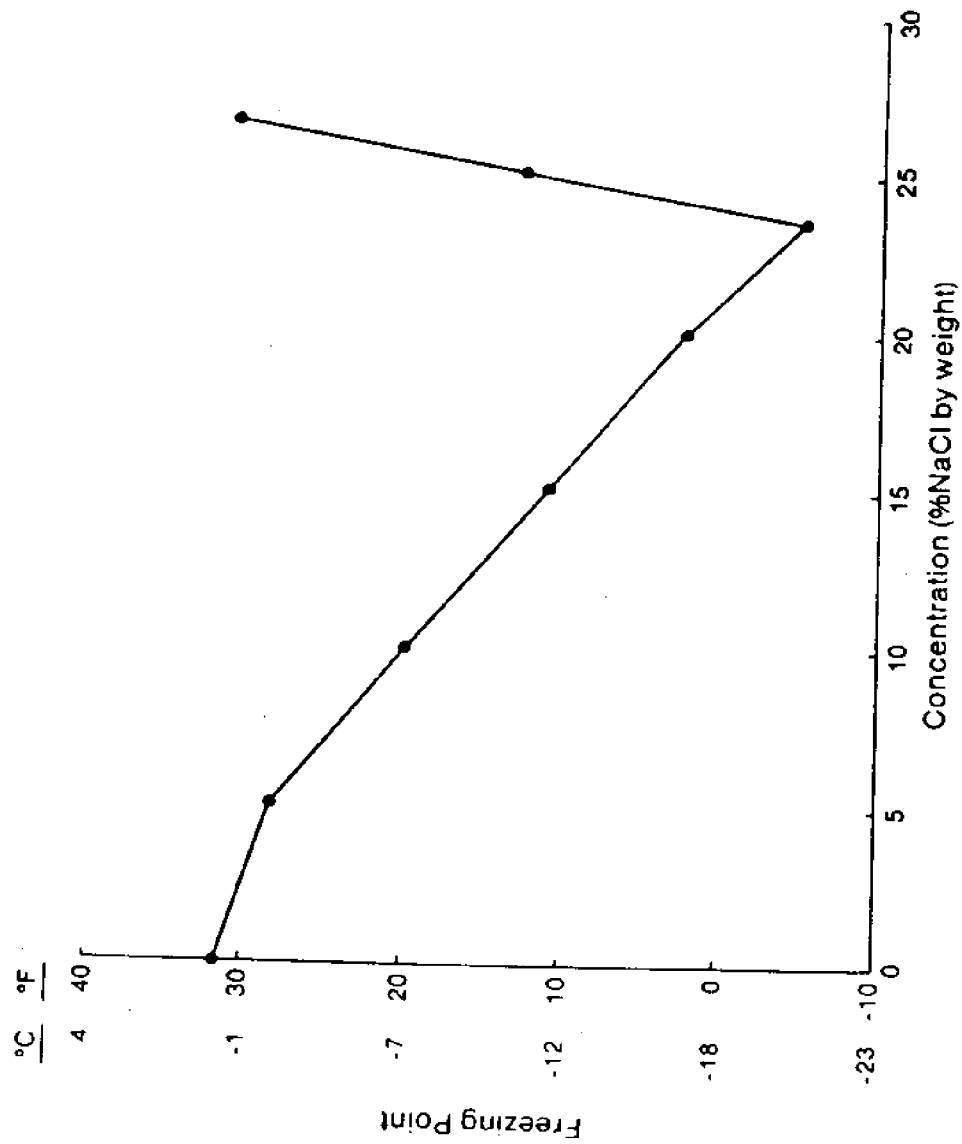


Figure 2 - Triangle Test for Crawfish Sensory Panel.

Crawfish Taste Panel Triangle Test

Of the three crawfish, can you detect one that is different?_____

List the number of those that you think are the same_____

different_____

If you can detect a difference, which do you prefer? the two which
are the same?_____

or the different one_____

If you have a preference, why?

For example: flavor, texture, etc.

Smoker_____

Non-smoker_____

Figure 3 - Nine Point Hedonic Test for Crawfish Sensory Panel.

Session _____ Date _____ Panelist _____ Sample Number _____

You are receiving one sample of crawfish to detect specific characteristics. Test the sample and evaluate it for overall acceptability, overall aroma, overall taste and overall texture. Then evaluate each of the individual characteristics, making sure that you only analyze it in the context that it is intended - i.e. aroma, taste and texture. If the sample has a positive connotation, circle "Good", if it has a negative connotation, circle "Bad". If you are not sure of the term's connotation, do not circle either "Good" or "Bad". If you do not perceive the characteristic, circle "0" and "1". If you do perceive the characteristic circle the intensity on the given scale.

OVERALL EVALUATION		NEGATIVE	POSITIVE	
Overall acceptability		-4 -3 -2 -1 0 +1 +2 +3 +4		
Overall aroma		-4 -3 -2 -1 0 +1 +2 +3 +4		
Overall taste		-4 -3 -2 -1 0 +1 +2 +3 +4		
Overall texture		-4 -3 -2 -1 0 +1 +2 +3 +4		

AROMA CHARACTERISTICS

	Good	Bad		DON'T PERCEIVE
Characteristic crawfish			-4 -3 -2 -1 0 +1 +2 +3 +4	
Aromatic			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Fresh			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Fishy			-4 -3 -2 -1 0 +1 +2 +3 +4	X
			-4 -3 -2 -1 0 +1 +2 +3 +4	X

TASTE CHARACTERISTICS

	Good	Bad		
Characteristic crawfish			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Sweet			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Salty			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Fresh			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Fishy			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Flavorfulness			-4 -3 -2 -1 0 +1 +2 +3 +4	X
After taste			-4 -3 -2 -1 0 +1 +2 +3 +4	X
			-4 -3 -2 -1 0 +1 +2 +3 +4	X

TEXTURE CHARACTERISTICS

	Good	Bad		
Tender			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Watery			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Grainy			-4 -3 -2 -1 0 +1 +2 +3 +4	X
Tough			-4 -3 -2 -1 0 +1 +2 +3 +4	X

COMMENTS

Any comments you have may be made here:

Figure 4 - Freezing profile of 3 pounds of crawfish (medium to large) in a brine tank chilled to -10°C .

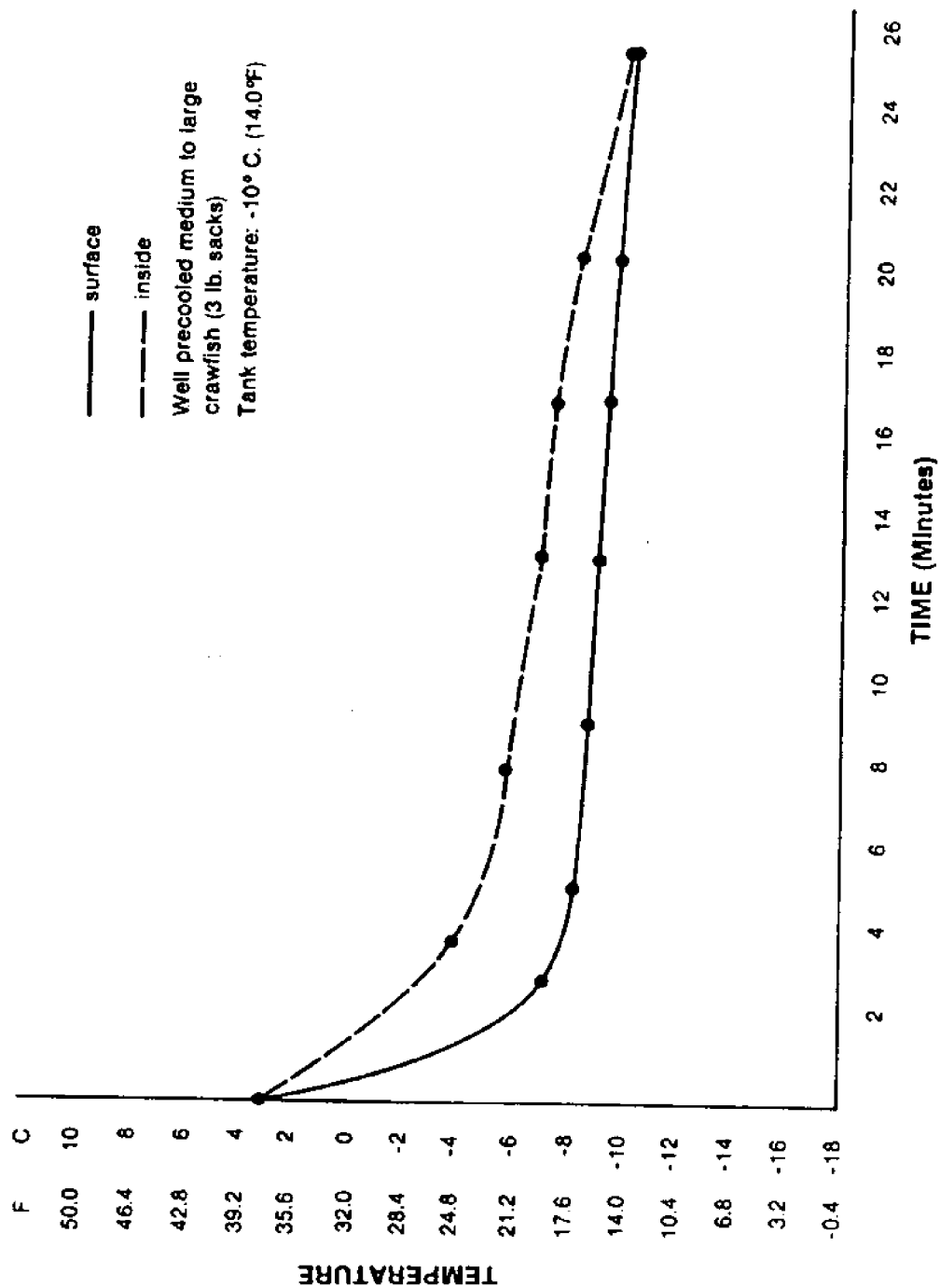


Figure 5 - Freezing profile of 3 pounds of crawfish (small)
in a brine tank chilled to -10°C .

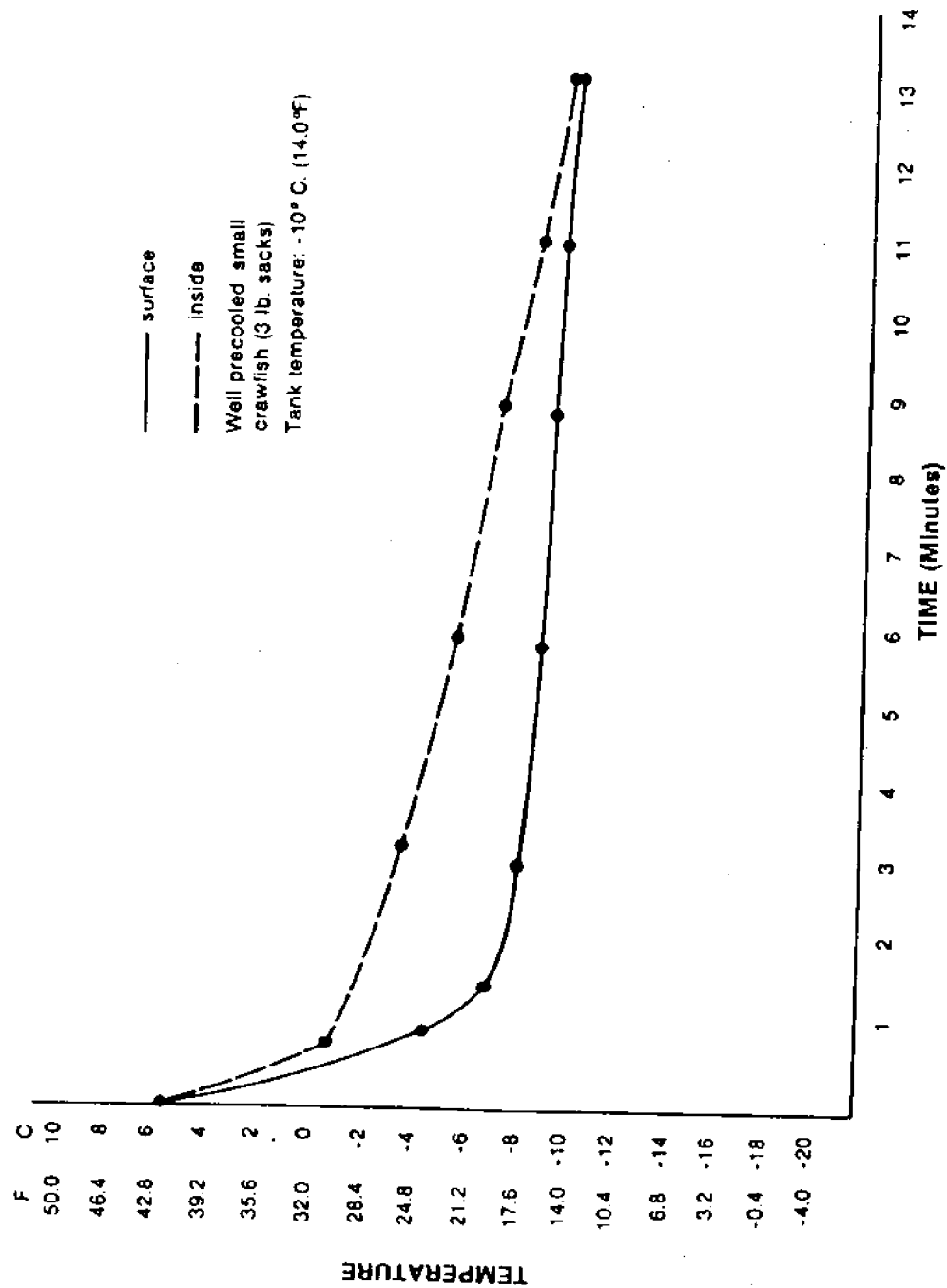


Figure 6 - Aerobic plate counts of brine frozen crawfish held in -20°C storage.

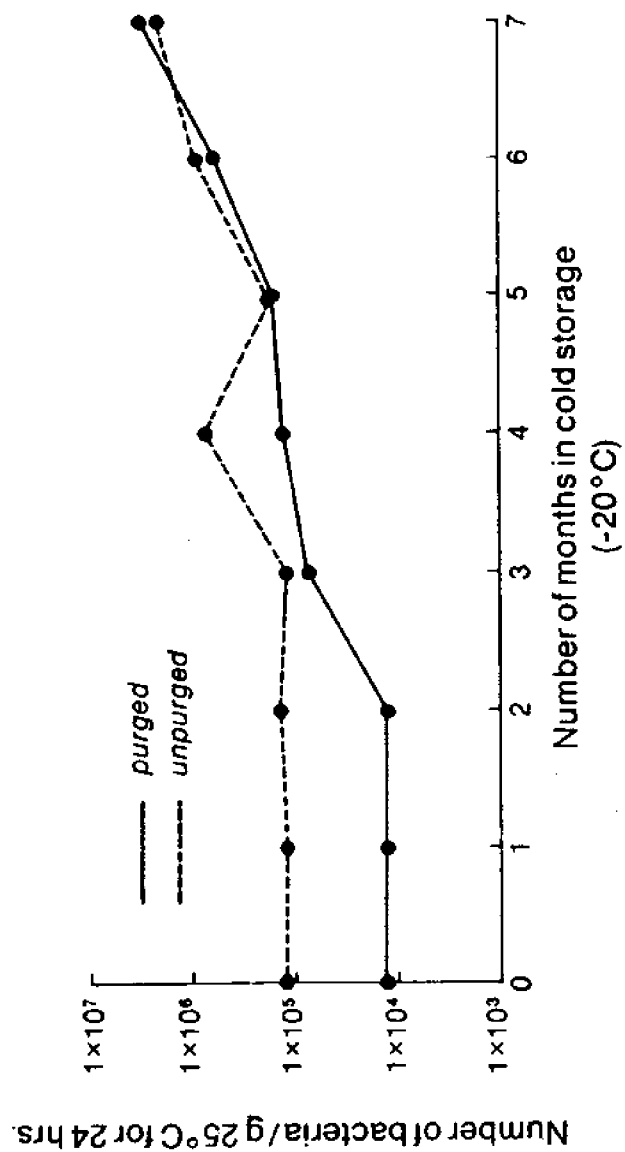
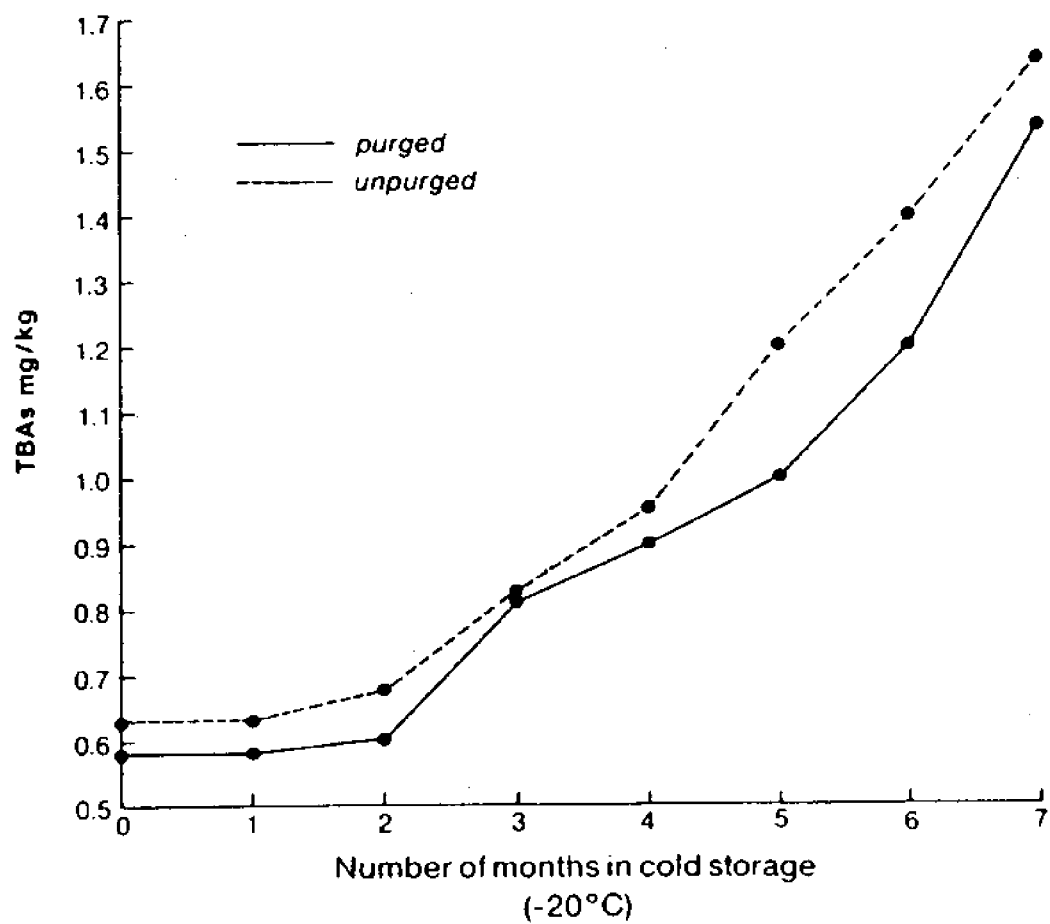


Figure 7 - TBA values of brine frozen crawfish held in
-20°C storage.



TEXTURE EVALUATION OF *Macrobrachium rosenbergii*

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INTRODUCTION

With seafood harvests at or near maximum sustainable yields (Lawrence et al., 1981) and the demand for fishery products increasing, aquaculture is rapidly becoming an important source of fish and shellfish on a worldwide basis. Numerous species have been studied for potential use in aquaculture, and extensive progress has been made toward the domestication of these species. One such example is the Malasian prawn, *Macrobrachium rosenbergii*. This species has emerged as an ideal organism for intensive culture while it offers the consumer an attractive alternative to the marine shrimp.

However, due to inherent texture and flavor differences between macrobrachium and penaeid shrimp, macrobrachium cannot presently compete successfully in the marketplace with penaeid shrimp. The texture of macrobrachium has been described by consumers as being "soft", "watery" or "mushy". In previous studies on sensory evaluation of macrobrachium and penaeid shrimp, the texture of macrobrachium was found to be considerably softer than that of penaeid shrimp (Ellis, unpublished data). Furthermore, there was a very large variation in texture of macrobrachium tail muscle. As quality uniformity is a critical factor in the marketing of a food product, this texture problem is presently an obstacle to the successful marketing of macrobrachium.

METHODS AND MATERIALS

Live, freshly harvested *Macrobrachium rosenbergii* obtained from aquaculture ponds in Brownsville, Texas were quick-killed in an ice slurry (1 part ice to 1 part water) and divided into two lots: those to be stored deheaded and those to be stored whole. Prawns to be stored deheaded were immediately deheaded with a sterile knife and rinsed carefully to remove any remaining hepatopancreatic tissues. Further subdivision by size was also done to reduce the large variation in texture found in preliminary trials. All prawns were then placed on ice and transported to the Seafood Technology laboratory at College Station, Texas where they were held on ice for ten days. Samples, taken on days 1, 2, 4, 8 and 10, were analyzed by both sensory and instrumental analysis.

Sample Preparation

Samples were cooked in boiling tap water according to prawn size and treatment: small, deheaded prawns for 3 minutes; large, whole and small, deheaded prawns for 4 minutes; and large, whole prawns for 5½ minutes. Cook-times were determined in preliminary trials and are defined as the times required to reach an internal temperature of 95-98°C as measured by a Leeds and Northrop temperature recorder. Immediately after cooking, the prawns were transferred to an ice bath (2 parts ice to 1 part water) for 2 minutes then held on ice until evaluation. Whole prawns were deheaded prior to serving.

Sensory Evaluation

The prawns were evaluated by a trained descriptive panel consisting of nine members, with selection and training based on the procedures of Cross et al. (1978) and Civille and Szczesniak (1973). Tests were conducted in the Meat Science sensory testing facility at Texas A&M. Panelists were seated in individual booths in which lighting and room temperature were controlled. Each booth was provided with a hooded dome through which the samples were passed, thereby separating the food preparation area from the testing area.

Eight prawns were evaluated in each session (four replicates per treatment), with prawns served one at a time. Prawns were served unpeeled in shallow plastic cups coded with three-digit random numbers. Order of sample presentation was determined by a balanced random block design.

Panelists were asked to peel each sample and evaluate the shell for shell hardness and adhesion of tissues (Figure 1). They were then instructed to turn the peeled tail muscle laterally and bite into the dorsal aspect of the first three segments to evaluate the remaining six attributes (Figure 1) according to the procedures described in Figure 2. Texture attributes, definitions and methods of evaluation were determined by the panelists during the first two training sessions.

Instrumental Analysis

Shear force was measured using an Instron Universal testing machine model 1122 equipped with a 10-blade Kramer shear compression cell. Full load, crosshead speed and chart speed were 500N, 50 ^{mm}/min and 100 ^{mm}/min, respectively. Quadruplicate samples were evaluated from each treatment.

Data Analysis

Texture panel data were analyzed by analysis of variance (ANOVA), while the Instron data were analyzed by analysis of covariance and least squares means.

RESULTS AND DISCUSSION

Sensory Evaluation

Analysis of variance indicated significant ($P < 0.01$) differences between deheaded and whole prawns in the various textural attributes, with the exception of gumminess (Table 1). Differences in adhesion of tissues, hardness of membrane, springiness, firmness and mushiness were all highly significant as they all had very high F-ratios (mean square treatment/mean square error). Gumminess however, only had an F-ratio of 1.38 (3.84 was required for significance at the 5% level) and was therefore not significantly affected by the prawns being stored whole or deheaded.

The significant difference ($P < 0.05$) in shell hardness between prawns stored whole and deheaded is somewhat interesting. Shell hardness is directly related to stage of molt: prawns in the post-molt stage have an extremely thin, flexible shell while those in the pre-molt stage have an extremely hard shell. Shell hardness therefore had a wide range of values, depending on when the prawn last molted. The significant difference observed in shell hardness between whole and deheaded prawns is most probably coincidental.

Storage time had a significant ($P < 0.01$) effect on all of the attributes except moistness and gumminess. Again, differences in firmness, hardness of membrane, mushiness, springiness and adhesion of tissues were all highly significant as they had large F-ratios. A ratio of 2.37 was required for significance at the 5% level.

There were significant differences between panelists' responses on all attributes. As each panelist provided consistent responses during the panel evaluation and on replicate samples from each treatment during each session, this difference between panelists is not considered very important. The most important factor to consider is consistency within each panelist.

Size of the prawn did not seem to significantly affect texture, with the exception of gumminess ($P < 0.05$). There was however, a significant difference ($P < 0.01$) in hardness of membrane: large prawns had harder shells than smaller prawns. Again, this difference is interesting yet purely coincidental.

The effects of treatment and storage time on firmness, springiness and hardness of membrane can be seen in Figure 3. Prawns stored deheaded had consistently firmer and springier tail muscles than those stored whole. Also, the external membrane surrounding the tail muscle was harder to penetrate in the deheaded prawns than in the whole prawns. Mean scores for these characteristics decreased during the first four days of storage, with whole prawns showing the greatest decrease (1.2 to 1.8 units on a scale of 1 to 8). Scores for deheaded prawns on the other hand only decreased 0.781 to 1.031 units or about one-third the decrease of whole prawns. After day 4, scores seemed to stabilize or increase slightly until termination of

the experiment. These characteristics seem to be related as they demonstrate similar patterns of change.

Mushiness and adhesion of tissues were inversely related to hardness of membrane, springiness and firmness as they increased with time, with whole prawns producing higher mean scores than deheaded prawns (Figure 4). Scores increased during the first four days of storage then seemed to stabilize. Increases were two to three times as great in whole prawns (0.532 and 0.562, respectively) than in deheaded prawns (1.687 and 1.375, respectively).

Moisture, gumminess and shell hardness showed no apparent increase or decrease with time (Figure 5). This observation was confirmed by analysis of variance. Deheaded prawns were generally more moist than whole prawns, while whole prawns were generally gummier and had harder shells. These differences however, are small and as stated earlier, they are not significant.

Instrumental Analysis

Shear force was significantly ($P < 0.0293$) greater in deheaded prawns than in whole prawns, thus indicating a firmer tail muscle in deheaded prawns than in whole prawns. Shear force decreased significantly ($P < 0.0001$) during storage, with minimum values occurring on day 4 (Figure 6). Minimum values for both firmness (sensory evaluation) and mechanical shear were also observed by Waters and Hale (1981) on day 4 of an 18-day iced-storage period for whole prawns. No explanation to this phenomenon was given.

Results of instrumental analysis are consistent with those of sensory evaluation. Figure 7 shows the relationship between firmness (sensory) and shear force. The relationship is fairly linear, thus indicating a good correlation.

CONCLUSION

Prawns deheaded immediately after harvest had significantly firmer and springier tail muscles than prawns left whole during iced storage. Whole prawns, however, were significantly mushier and had a greater degree of adhesion of tissues to the shell upon peeling than deheaded prawns. This adhesion of tissues to the shell can sometimes produce an unsightly tail muscle and is therefore to be considered undesirable to the consumer.

During the 10-day storage period, firmness, springiness and hardness of membrane decreased while mushiness and adhesion of tissue increased in both whole and deheaded prawns. These changes were more pronounced in whole prawns than in deheaded prawns. As these changes were never more than 2 units on a scale of 1 to 8, they are to be considered minimal. A consumer panel is now needed to determine preferences between prawns stored deheaded or whole.

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Table 1. F - ratios (mean squared x/mean squared error) for sensory evaluation of *Macrobrachium rosenbergii* stored on ice.

F - ratio				
	Treatment	Time	Panelist	Size
Shell Hardness	4.48*	3.34**	5.84**	26.60**
Adhesion of tissues	54.94**	4.02**	7.96**	<1
Hardness of membrane	48.45**	10.39**	17.57*	<1
Springiness	44.49**	5.99**	5.75**	<1
Moistness	10.51**	1.97	11.76**	2.28
Firmness	38.54**	12.92**	7.92**	<1
Mushiness	56.31**	6.73**	7.49**	<1
Gumminess	1.38	<1	19.76**	4.17*

*Significant at $P < 0.05$

**Significant at $P < 0.01$

Name:

Date:

Sample	Shell	Adhesion of	Hardness of

Figure 1. Questionnaire used to evaluate prawn texture

SHRIMP TEXTURE PANEL

Turn the prawn laterally, with the tail turned either to the left or the right, and bite into the dorsal aspect of the first three segments. Evaluate the prawns for:

CHARACTERISTIC	DEFINITION	STAGE OF MASTICATION
Shell Hardness*	Shell hardness; resistance to breakage	Press empty shell between thumb and index finger
Adhesion of tissues*	Degree to which tissues adhere to the shell	Amount of tissues remaining in shell after peeling
Hardness of membrane	Force required to penetrate the external membrane surrounding the tail muscle tissues	Taken at the first bite, using the front teeth
Springiness	Rate at which the deformed tissues regain original shape; bounce	Taken at the first bite (front teeth) and the first chew (molars)
Mushiness	Combination of adhesiveness and fragility; mealy, lack of consistency	Taken from the first chew (molars) to just prior to swallowing
Firmness	Force required to rupture the shrimp tissues	Taken from the first chew (molars) to just prior to swallowing
Gumminess	Degree to which the tissues adhere to the teeth	Taken from the second chew (molars) to just prior to swallowing
Moistness	Amount of moisture present in the shrimp tissues	Taken from the first bite (front teeth) to just prior to swallowing
*Evaluate before first bite		

Figure 2. Definitions and methods of evaluating the various texture characteristics of *Macrobrachium rosenbergii* held on ice.

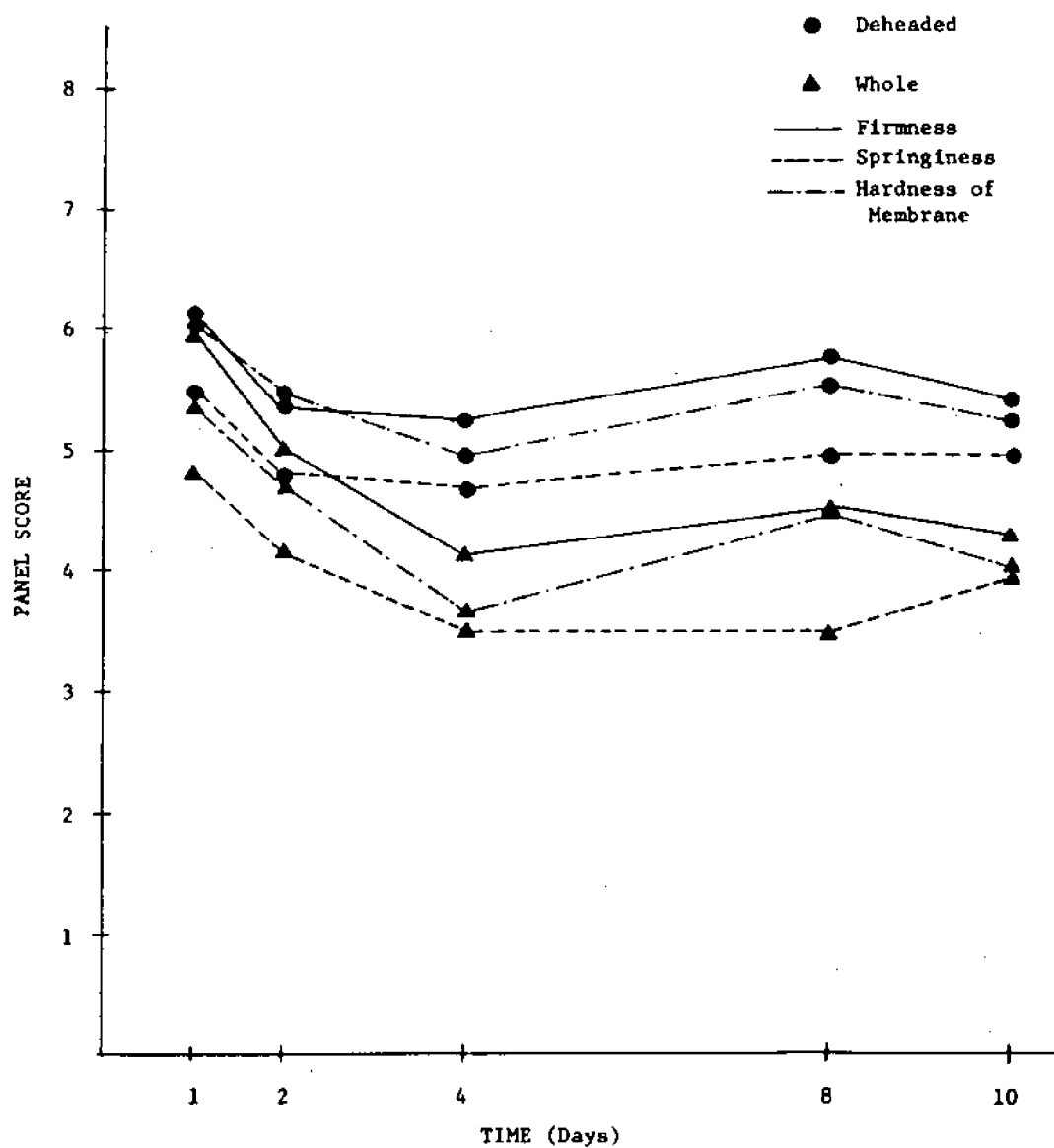


Figure 3. Mean firmness, springiness and hardness of membrane scores for *Macrobrachium rosenbergii* stored on ice.

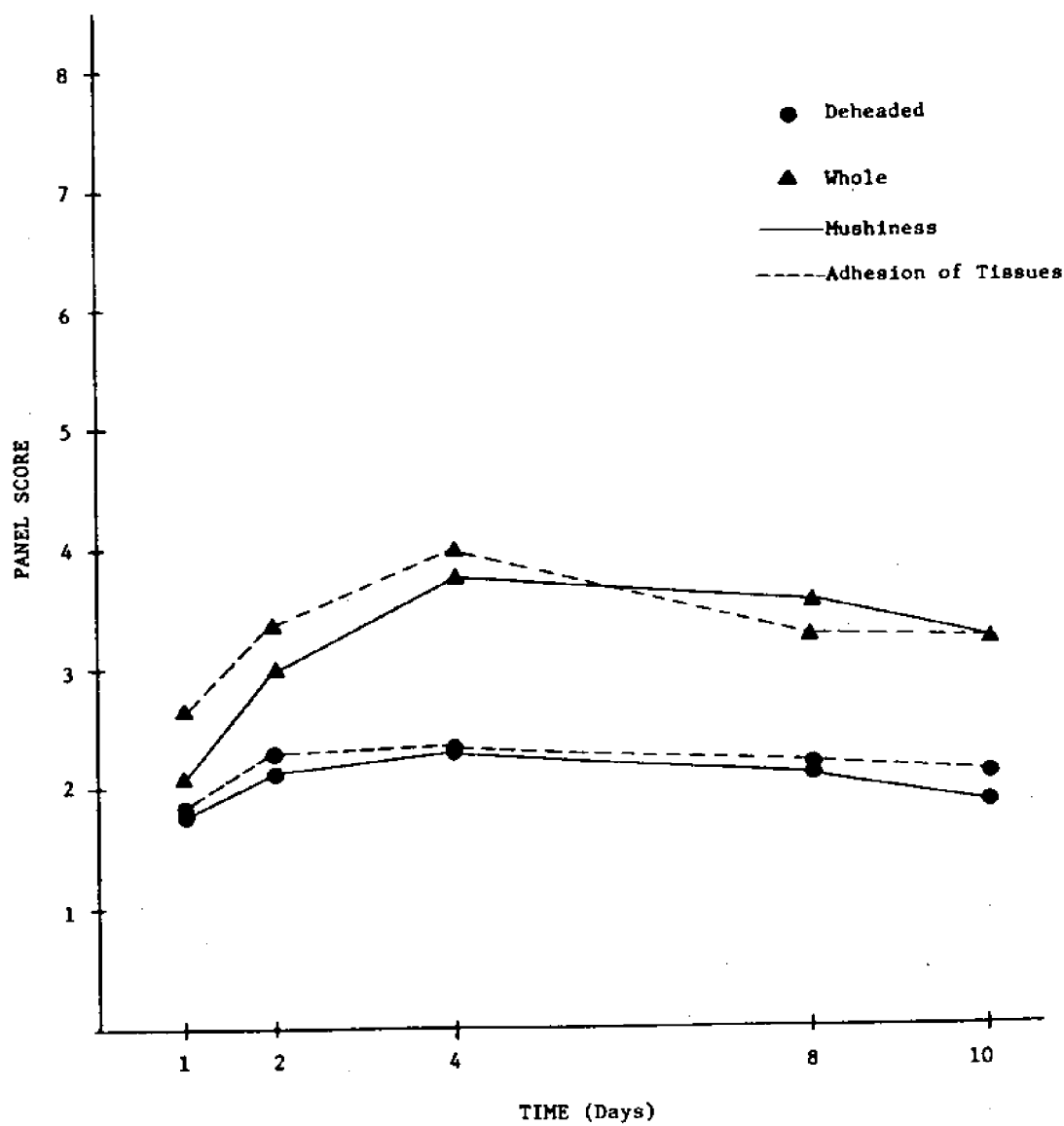


Figure 4. Mean mushiness and adhesion of tissues scores for *Macrobrachium rosenbergii* stored on ice.

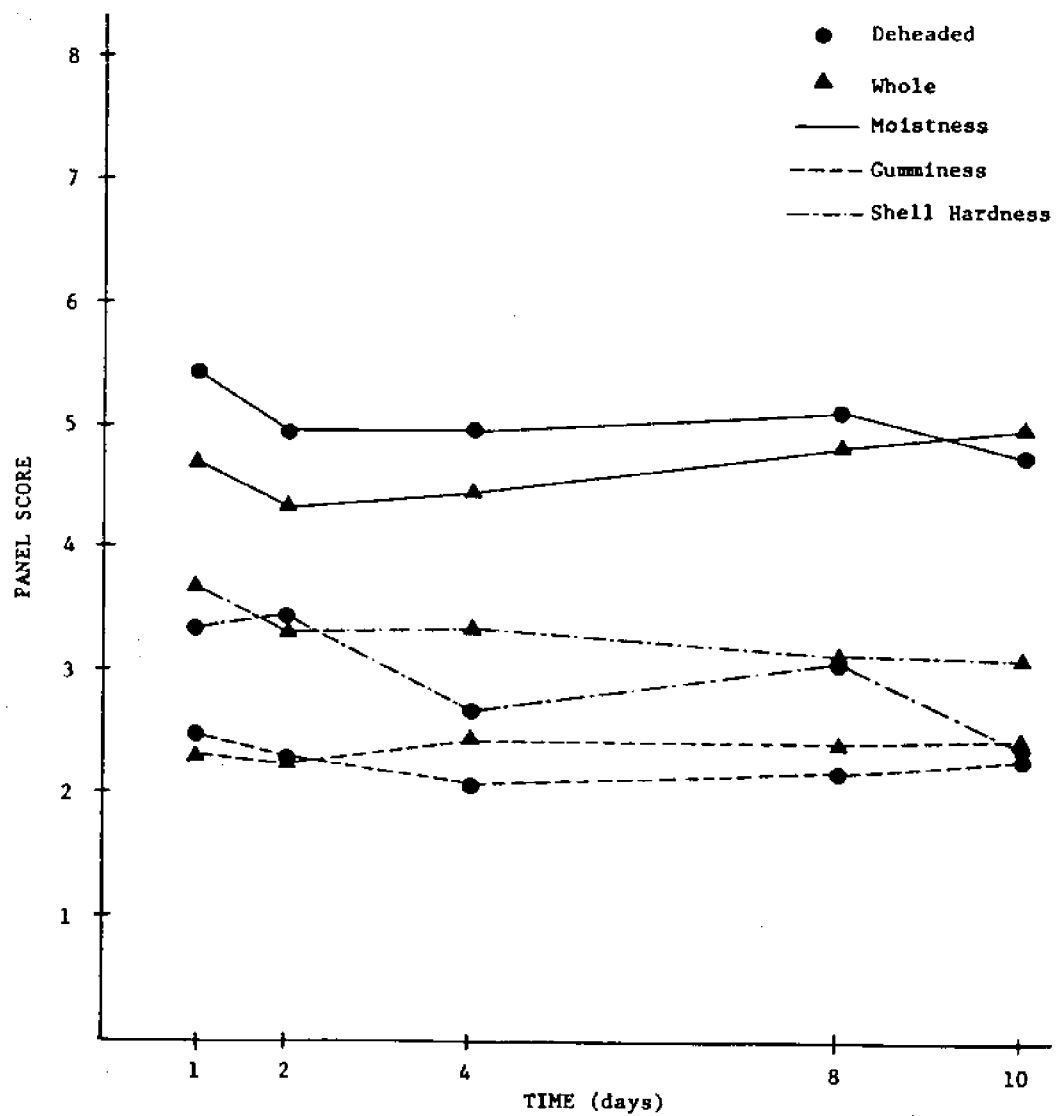


Figure 5. Mean moistness, gumminess and shell hardness scores for *Macrobrachium rosenbergii* stored on ice.

Kramer Shear Press values for
Macrobrachium rosenbergii stored on ice

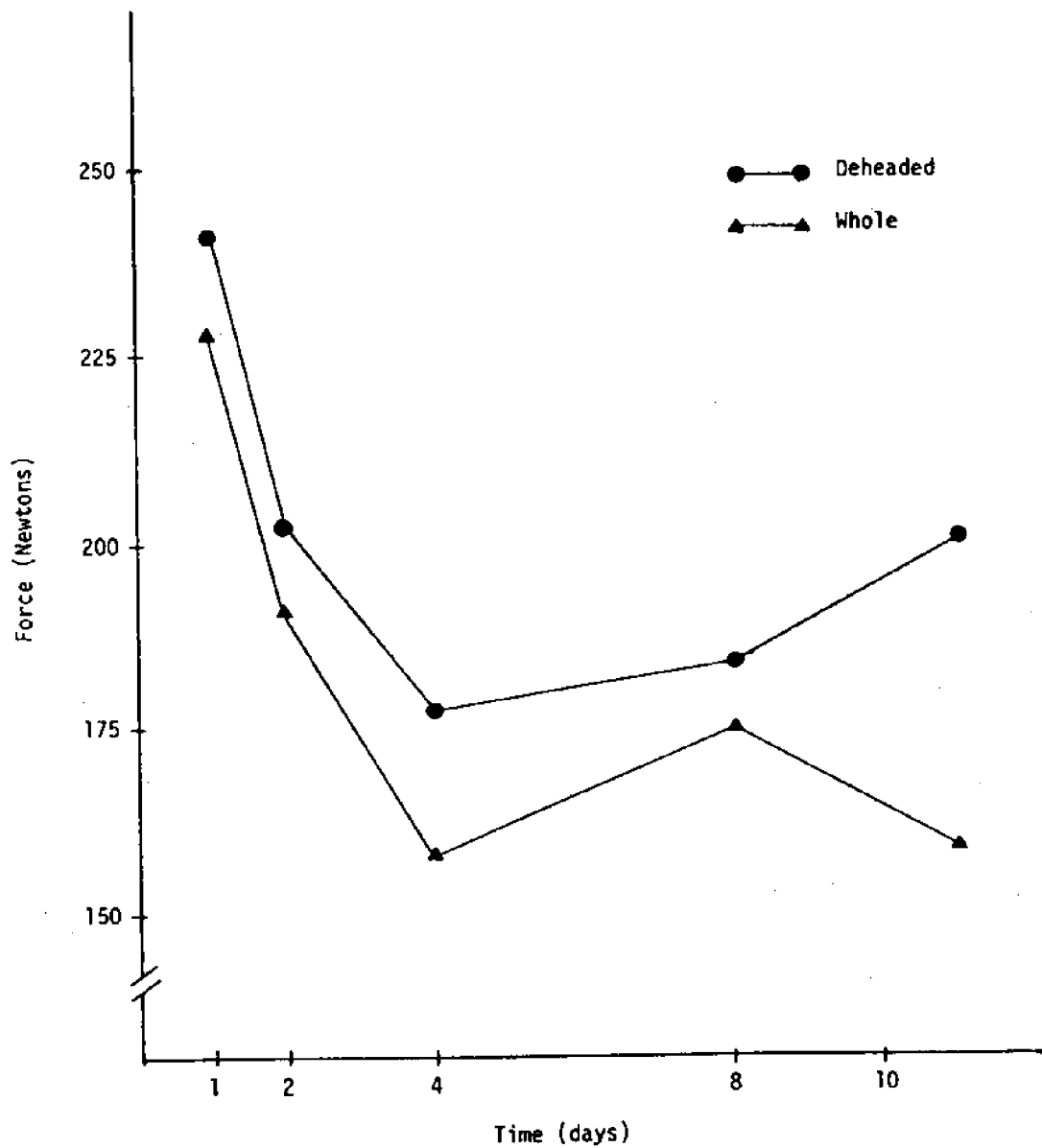


Figure 6. Kramer shear force for *Macrobrachium rosenbergii* stored on ice.

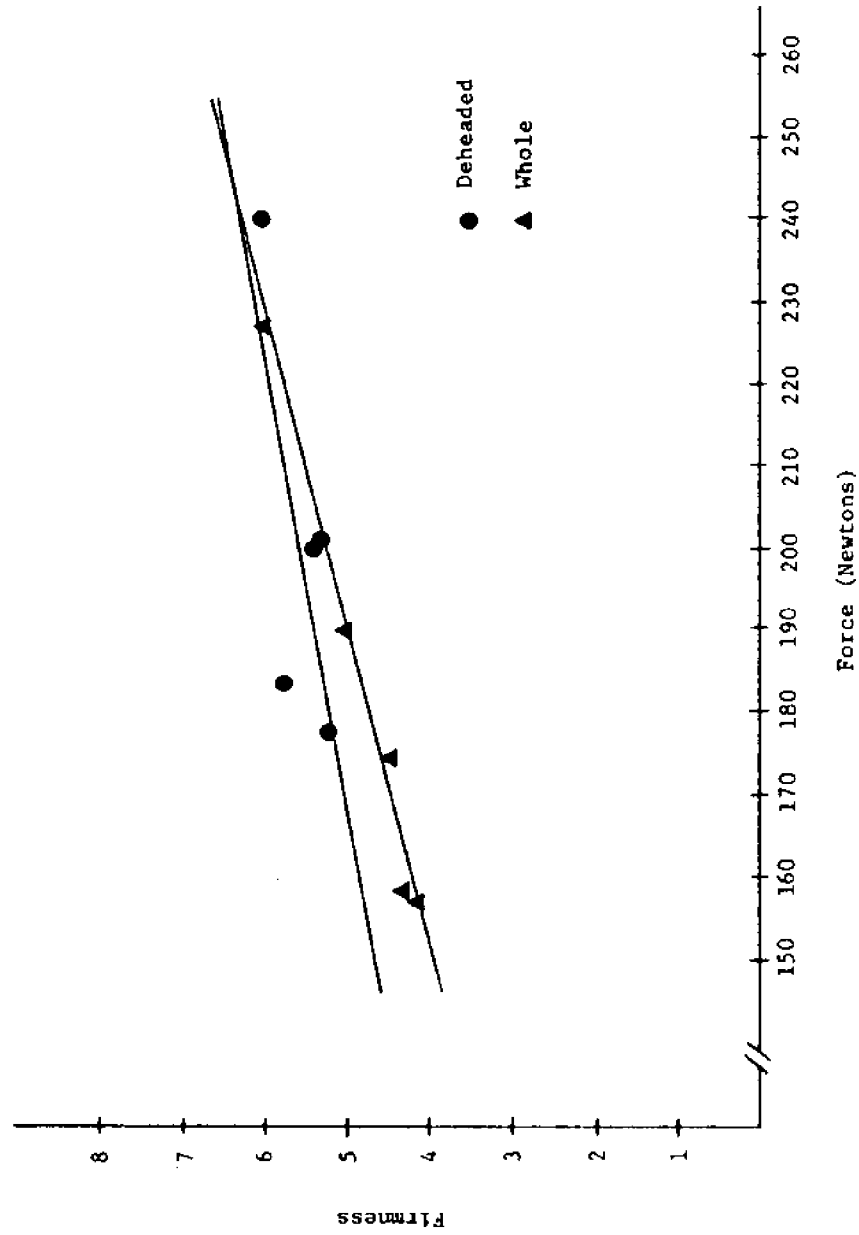


Figure 7. Correlation between sensory and instrumental analysis for *Macrobrachium rosenbergii* stored on ice.

Thawed Lobster Tails: Some Quality Changes

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INTRODUCTION

Lobster tails are generally stored frozen at about -20 C during wholesale storage and distribution, however, at the retail level it is not uncommon for them to be displayed on ice for varying periods of time. There are wide differences of opinion regarding the shelf-life of lobster tails with suggested times ranging from 1.5 to 10 days, regardless of the origin of the tail (2,5,6,10). These recommendations were based on such observations as microbial counts, enzymatic digestion around the gut tissue, organoleptic changes and blackspotting. Due probably to the expense involved, relatively little work has been done on the storage characteristics of this product (3).

With a rising demand for lobster tails by consumers as well as their increased awareness of "seafood quality," it was considered necessary to have a better understanding of the quality changes that occur in lobster tails during periods of iced storage. Therefore, a study was initiated on the shelf-life characteristics of lobster tails from a warm and a cold water source, Florida and South Africa respectively.

MATERIALS AND METHODS

Frozen Florida and South African lobster tails were obtained from various wholesalers in Florida. The tails were stored, ventral side down, on ice in a 4 C refrigerator for up to 12 days. Aerobic plate counts (APC) and tyrosine values were determined using duplicate tails on days 1,3,6,9 and 12. APC's were determined using standard procedures (7) on the exposed muscle portion with incubation at 25 C for 5 days. Soluble tyrosine values were determined on a midsection portion of the tail meat using the Hull method (4) by preparing a 1:10 dilution with 5% trichloroacetic acid solution to precipitate the protein. A Bausch and Lomb Spectronic 20 was used to measure the absorbance at 650 nm. Each study was conducted in duplicate.

Sensory evaluations were conducted on lobster tails stored 0, 5 and 10 days on ice with taste panelists rating them for odor, texture, color, flavor and general acceptance. A scale ranging from "like extremely" to "dislike extremely" with nine gradations was used. A total of 30 panelists evaluated both the Florida and the South African tails at different times. Each panelist received a portion of the tails to be tested from the same location on the tail. That is, a panelist would receive all top, midsection or lower tail portions for evaluation. Statistical analysis using Duncan's Multiple Range test was conducted on the taste panel results

by giving the "dislike extremely" category a numerical value of 1 ranging up to the "like extremely" category which received a value of 9.

RESULTS AND DISCUSSION

It has been suggested that the flesh of crustaceans spoils at a much faster rate than finfish (3). This statement is based on the observation that crustacean flesh contains higher amounts of free amino acids, which can serve as substrates for the growth of microorganisms. This substrate availability may explain, in part, the rapid increase in aerobic plate counts recorded for both the Florida and the South African tails during the storage period (Figure 1). The Florida tails reached levels of about 10^6 /g by the 4th day of storage, whereas, the South African tails reached this count on the 6th day. By the 12th day counts were at 10^8 /g for both types of lobsters. It is noteworthy that the South African tails at zero time had APC's of about 40,000/g, whereas the Florida tails averaged over 100,000/g. These counts, while high, are on the average less than those previously reported for similar products (8), in which the reported geometric mean for APC counts on lobster tails obtained at 30 C was 140,000/g and ranged from 80-2,200,000,000/g.

The texture of lobster meat is firm to tough, and it was anticipated that the tyrosine values would increase as the tails underwent autolytic and microbial changes which should result in a softening of the texture of the meat. The tyrosine values, shown in Figure 2, did increase, however, the panelists did not indicate unsatisfactory texture changes (Table 1). In fact, the panelists perceived a slight improvement in the texture of the Florida tails following 5 days of iced storage. The decrease in tyrosine values between day 6 and 9 is attributed to the rapid growth of bacteria with the subsequent utilization of the available amino acids.

Table 1: Taste panel evaluations for iced Florida and South African lobster tails (n=30)

	General Acceptance	Odor	Texture	Color	Flavor
Florida:					
0 days	7.00 ^a	6.77	6.45	7.10	6.83
5 days	6.70 ^a	6.67	6.86	5.87	6.70
10 days	4.63 ^b	5.57	6.10	4.97	4.90
South African:					
0 days	7.93 ^c	7.23	7.60	7.50	8.03
5 days	7.47 ^c	6.73	7.43	7.17	7.53
10 days	6.73 ^d	6.83	7.23	6.20	7.13

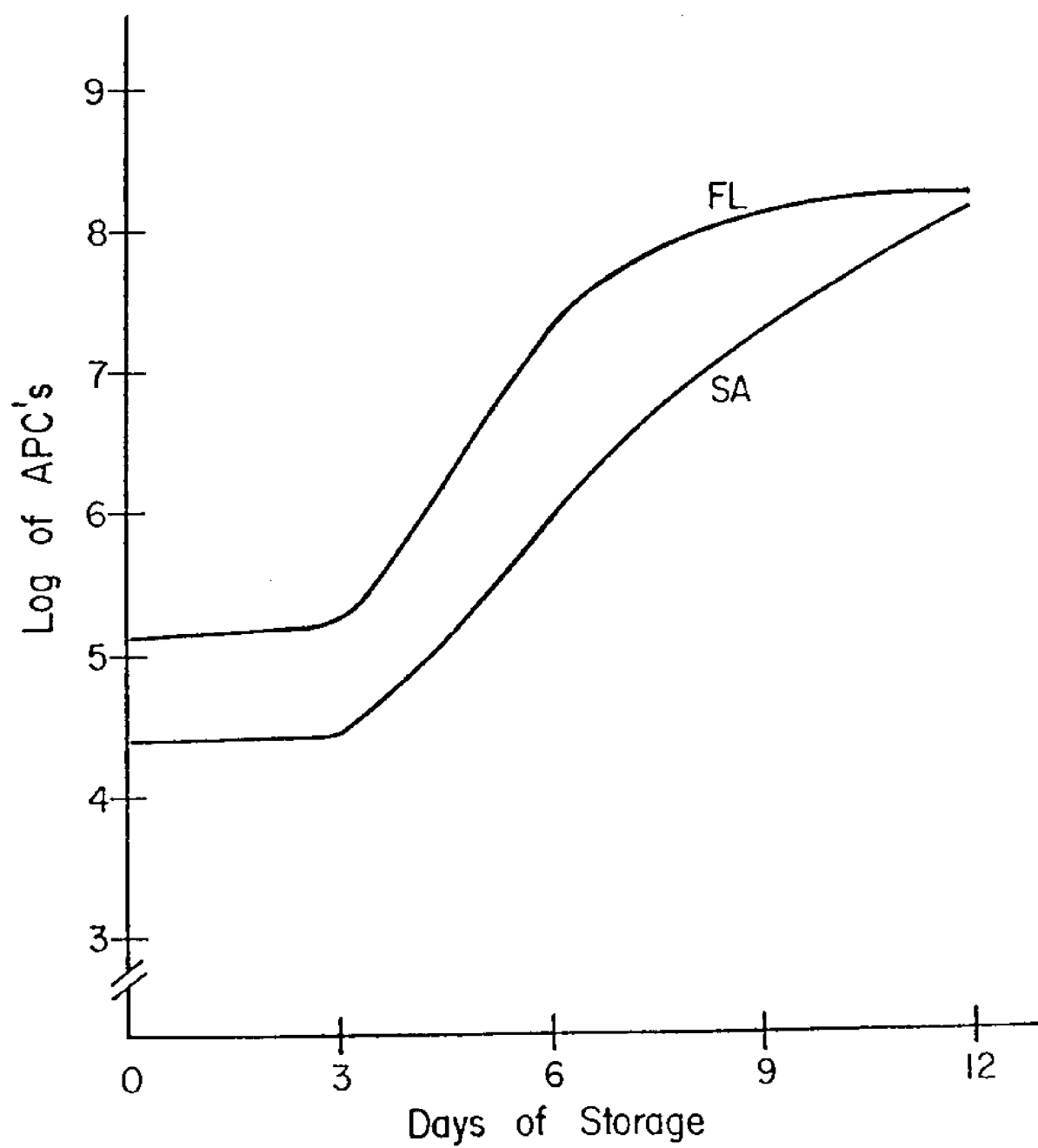
^a at p=.05, no significance between these values

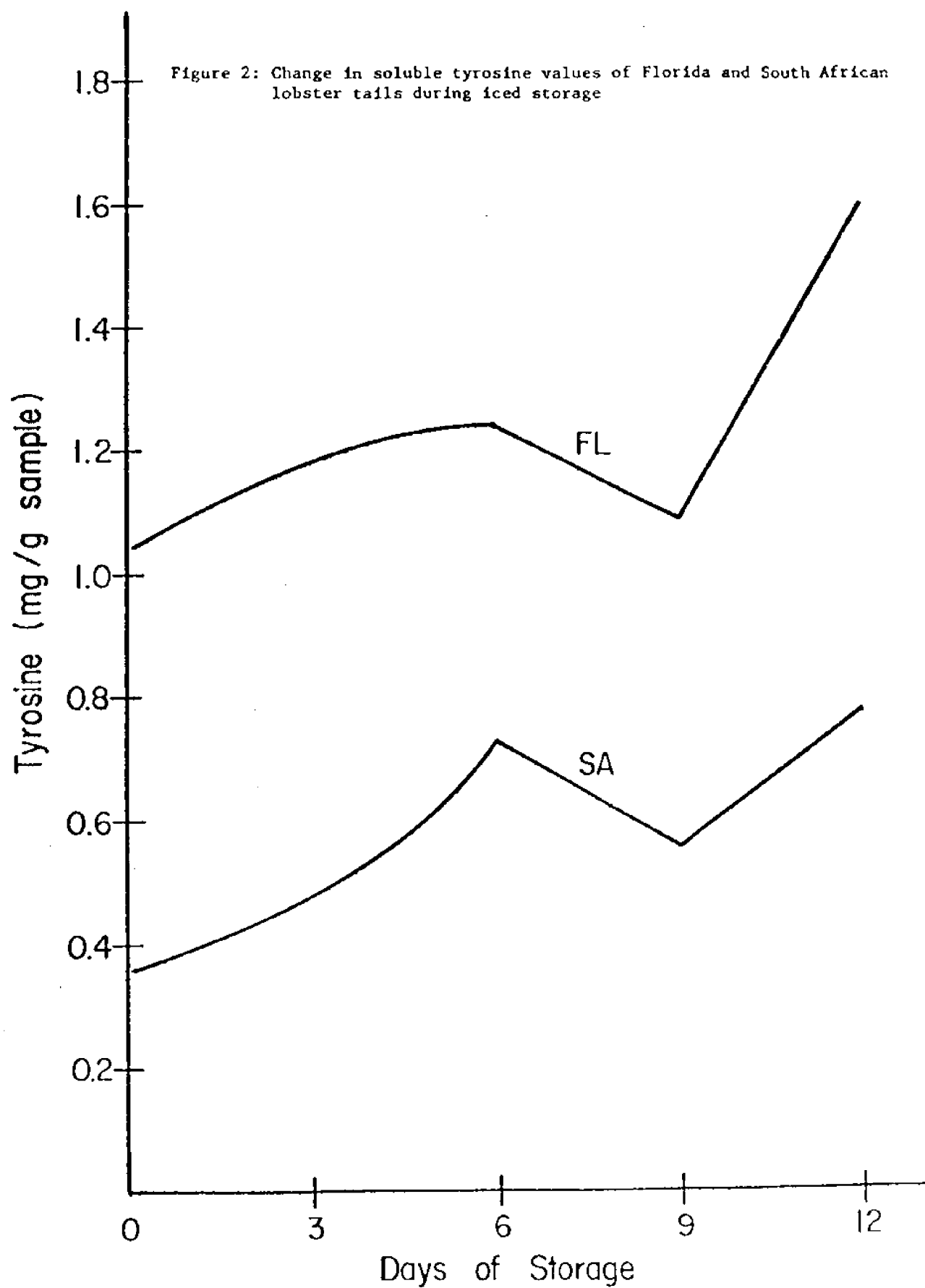
^b at p=.05, significant difference between this value and ones marked ^a

^c at p=.05, no significance between these values

^d at p=.05, significant difference between this value and ones marked ^c

Figure 1: Aerobic plate counts of Florida and South African lobster tails during iced storage





Sensory scores determined by the panelists are shown in Table 1. There are a number of interesting observations that can be made from these data relating to shelf-life of the two kinds of tails. The most obvious difference is the rapid loss of acceptability of the Florida tails following 5 days of storage, whereas the South African tails did not exhibit as rapid a decline in acceptability. These data show that acceptability was significantly less at 10 days as compared to 5 days for both the Florida and South African tails at the 95% confidence level, with the greatest numerical difference occurring with the Florida tails. Marked melanosis and strong ammoniacal odors were apparent at the 10th day of storage for the Florida tails. This may be related to the higher level of free amino acids in the Florida tails as compared to the South African tails. As shown in Figure 2, the tyrosine level in Florida tails is more than twice that of the South African tails, and it should be noted that South African tails developed melanosis to a much less degree than the Florida tails.

The melanosis, depending upon the individual tail, first developed in the anal section between the 2nd and 5th day and then spread up the tail on the outer edges of the belly section. The black-spotting was also apparent on the meat after cooking and removal of the shell. This discoloration was due mainly to intense blackening of the membrane (hypodermis) that separates the meat from the shell. Individual differences were noted among tails from the same lot and were attributed to such factors as stage of molting, previous handling, presence of bisulfite, etc. In a number of individual tails this blackening was so objectionable in the cooked meat of Florida tails that the samples were considered unfit to present to the panelists. In addition, other forms of darkening have been described for crustaceans due to reactions between the copper present in the blood and sulfides and ammonia produced during microbial growth (9).

These data indicate that the maximum thawed shelf-life of lobster tails would be about 5 days with black-spotting and off-odors apparent at this time. The warm water tails from Florida undergo a much more rapid loss of quality than do the cold water tails of South Africa. This difference is probably related to the higher free amino acid content of the warm water tails resulting in more rapid microbial growth with the concurrent production of off-odors. The reason for the more rapid black-spotting of the Florida tails may also be related to the higher levels of available tyrosine present in this species of lobsters.

Based on the data of this study, it appears that up to 5 days of iced storage is possible with thawed lobster tails. This is mainly due to pronounced black-spotting that occurs as well as off-odors that are produced (1). Due to the biological variation within the tails and differences in handling procedures among fishermen, this storage time is probably the maximum available before marked consumer dissatisfaction occurs.

ACKNOWLEDGMENT

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A POSSIBLE ON-BOARD HANDLING TECHNIQUE
FOR IMPROVING SHELF-LIFE OF FISH

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INTRODUCTION

With the increasing fuel costs and the closure of Mexican fishing waters there has been a trend among Texas shrimp fishermen to diversify their operation. Many shrimp boats have entered into a bottom fish fishery. These boats have changed to fishing bottom long-line systems for red snapper (Lutjanus campechanus), yellow edge grouper (Epinephelus flavolimbatus), and golden tilefish (Lopholatilus chamaeleonticeps).

The handling techniques for fin fish, as compared to those for shrimp, require some modification, with minimum modifications to the shrimp boat.

The majority of the boats entering this fishery use ice holds to preserve their catch while at sea. Ice is an effective method of chilling and holding shrimp, but because of the larger mass of these fish, chilling technique must be modified before the fish is stored below.

Members of this industry requested assistance in developing on-board handling techniques to improve the quality of bottom fish. We looked at chilling rates, the use of a chemical dip, over-all on-board handling of the fish and how these variables affected the bacteria counts of the belly lining.

MATERIAL AND METHODS

Total microbial surface counts of red snapper and internal temperatures were monitored during the catching, landing, and at the wholesale level. Fish were treated with a 30 min dip in a 13% solution of Fish Plus (B K Ladenburg Phosphates) solution, ice and seawater and without the phosphate dip in seawater & ice (chill tank) for 30-60 min (until internal temp = 4°C).

The fish were stored below deck and well iced with shaved ice.

Upon arrival at the dock, Rockport, Texas, the fish were removed from the hold by melting the ice with fresh water and by conveyor, dropped into a thaw tank, conveyed from the thaw tank to a scale, weighed and placed in a wooden shrimp box with ice.

Fish were transported to the wholesaler, Dallas, Texas, by truck overnight and processed for the retail market.

The first sampled fish was stored for 10 days (from hook to wholesaler).

A second evaluation of the chemical dip was made in a land based mobil laboratory. Ten red snapper were monitored for a total microbial surface count over a period of 18 days while stored on ice.

RESULTS AND DISCUSSION

Long-line systems produce a high quality fish, as they are not dragged or bruised in a trawl and they are often brought aboard in a live state. The affects of hauling these fish from deep water is thought to be minimal on the flesh quality.

The internal temperature of fish caught in early May 1984 in 34 fathoms (204 ft.) of water in the Gulf of Mexico, SSE of Port Aransas, was between 19.0-20.8°C (Table 1 & 2).

After hauling the fish aboard the hook was removed and the fish was gutted and washed with a seawater deck hose; this procedure took 3-4 min depending on the amount of fish being caught. If the fish were to go in the chill tank they were immediately placed in the tank. The chill tank temp ranged from -2°-+1°C. If the fish were to go below on ice it took another 5-12 min because it would require 2 men to remove the hatch and lower the fish (often the fish were dropped 8 ft into hold).

While the fish was on deck the internal temp did not significantly change, however, the flesh in the cheek of the fish rose to 23°C.

After 14 hr. on ice the fish had an internal temp of 6.6°C. The fish in the chill tank had an internal temp of 1.5°C in 1.5 hrs.

Table 1. Time & Temp Changes of
Fish from hook to Ice-hold (without chill tank)

(Water temp = 23.0°C) (Ambient temp = 25.6°C)				
Landed (0 min) (20.4°C)	Gutted	Washed	Below (8-16 min) (Check = 23°C)	Iced (14 hrs.) (6.6°C)

Table 2. Time & Temp Changes of Fish
from Hook to Ice-hold (through chill tank).

(Ambient temp = 24.7°C) (Water temp = 23.0°C)				
Landed (0 min) (19.3°C)	Gutted	Washed	Chill Tank (-2° - +1°C) (3-4 min) (19.3°C)	Iced (1.5hr) (1.4°C)

Bacteria counts were only made on fish which went through the chill tank (with and without dip) (Fig 1).

The treated and untreated samples had similar counts out of the chill tank. This is attributed to a comingling of bacteria in the tank.

When this was observed additional samples were taken and the fish was washed before sampling and a classic 1 log reduction in bacteria was observed.

A similar observation was made after sampling upon unloading. This again is attributed to the comingling of bacteria in the thaw tank at the dock.

However, the difference in the counts at the wholesaler (dipped 2.4×10^4 & control 8.0×10^6 bacteria cc2) is believed to be attributed to the bacteriacidal affects of the Fish Plus on the dipped samples.

The wholesale buyer also noticed a physical difference between the treated and untreated fish. He commented that a nine day old treated fish appeared to be 4-5 days old.

Because of the apparent comingling action in the chill tanks and thaw tanks we attempted to conduct a more controlled study from a shore based laboratory. The treated fish in this study started out a much lower bacterial count (ca 2 logs). This may be due to a physical washing action of the fish being placed in the dip for one minute and probably caused by a combination of the bacteriacidal action of the Fish Plus and the washing. At 8 days on ice the untreated fish were obviously beginning to spoil and now had a 3 log higher count. At the end of the 18 day period the untreated fish were obviously spoiled and the dipped fish were just beginning to show signs of spoilage (Figure 2).

CONCLUSIONS

While most of us look for a "magical chemical" to solve all our quality control problems, more often than not our problems can be solved with old fashioned "elbow grease". Gutted and washed fish had a surface bacteria count of about 3 logs and this is probably a manageable goal aboard the type vessels we are fishing in our industry today.

If possible the fishermen gutting the fish should not handle bait while gutting fish. This statement is easy to make when your feet are firm on dry ground but as is often the case, it is one of those nice to have things when the deck below you rolls and pitches.

Because the fish of the Gulf of Mexico are coming out of warm water it is almost a must to use a chill tank on-board. The natural flora associated with these warm water fish would be greatly controlled by a quick chilling in maintaining the fish at less than 4°C. It appears that the chill tank is the most efficient means of accomplishing this. After chilling in the chill tank, it is also recommended that the fish be washed once again with seawater hose, while this may warm the fish slightly the internal flesh does not warm significantly. Then if a dip is desired to be used, it should be used at this time. This would allow one to use a smaller amount of dip.

The potential for abusing a chemical additive is always present and the users should always be aware of this possible abuse. Fish Plus was designed to be used on fish filets which were to be frozen. It appears that this product may be effective in prolonging the shelf life of gutted fish and it is possible to use this product at sea.

Because these long-lined fish come aboard at such a high quality, the fish should be handled as little as possible throughout the distribution system.

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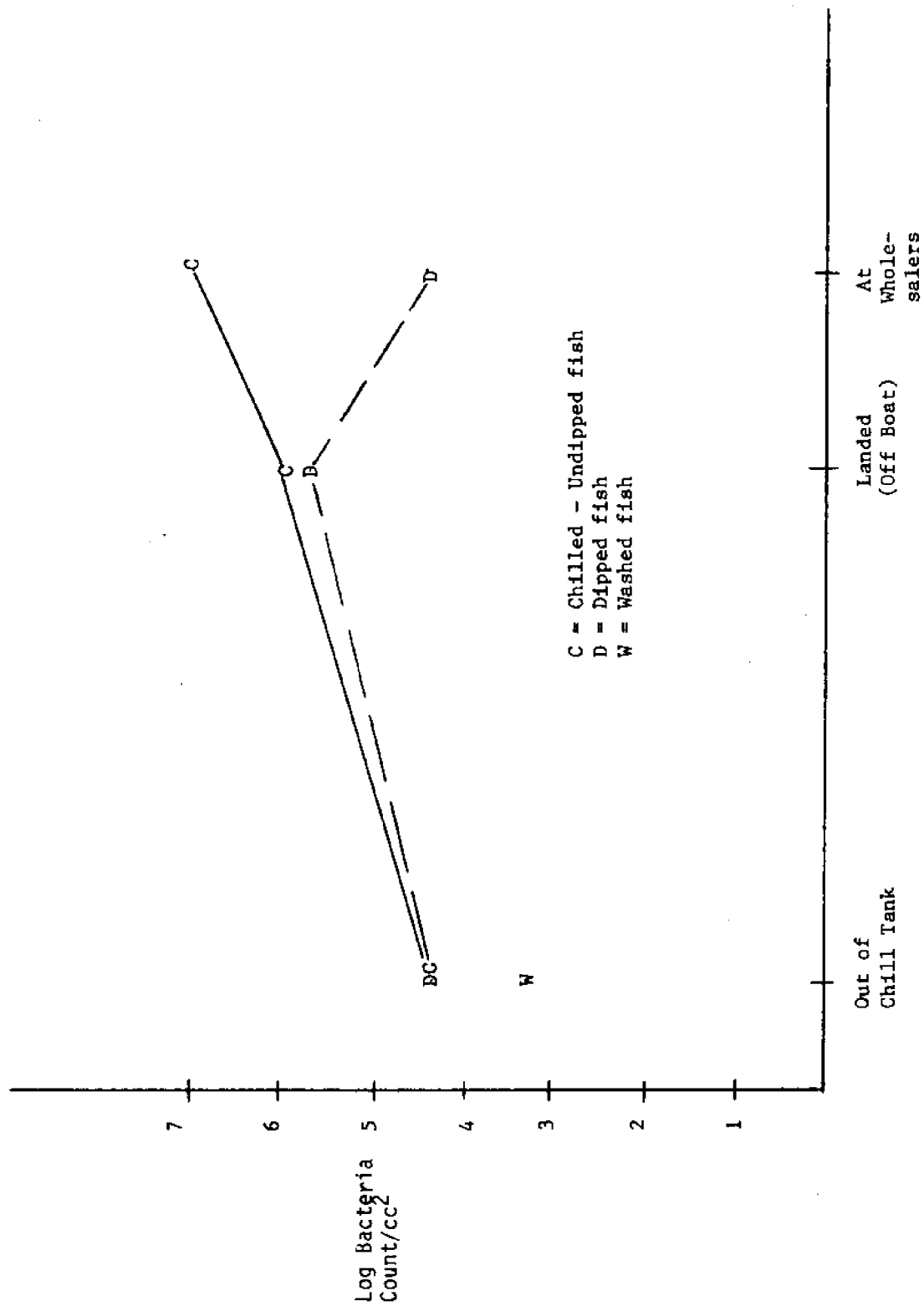


Fig. 1 Mean total microbial surface counts of iced red snapper from hook to wholesale.

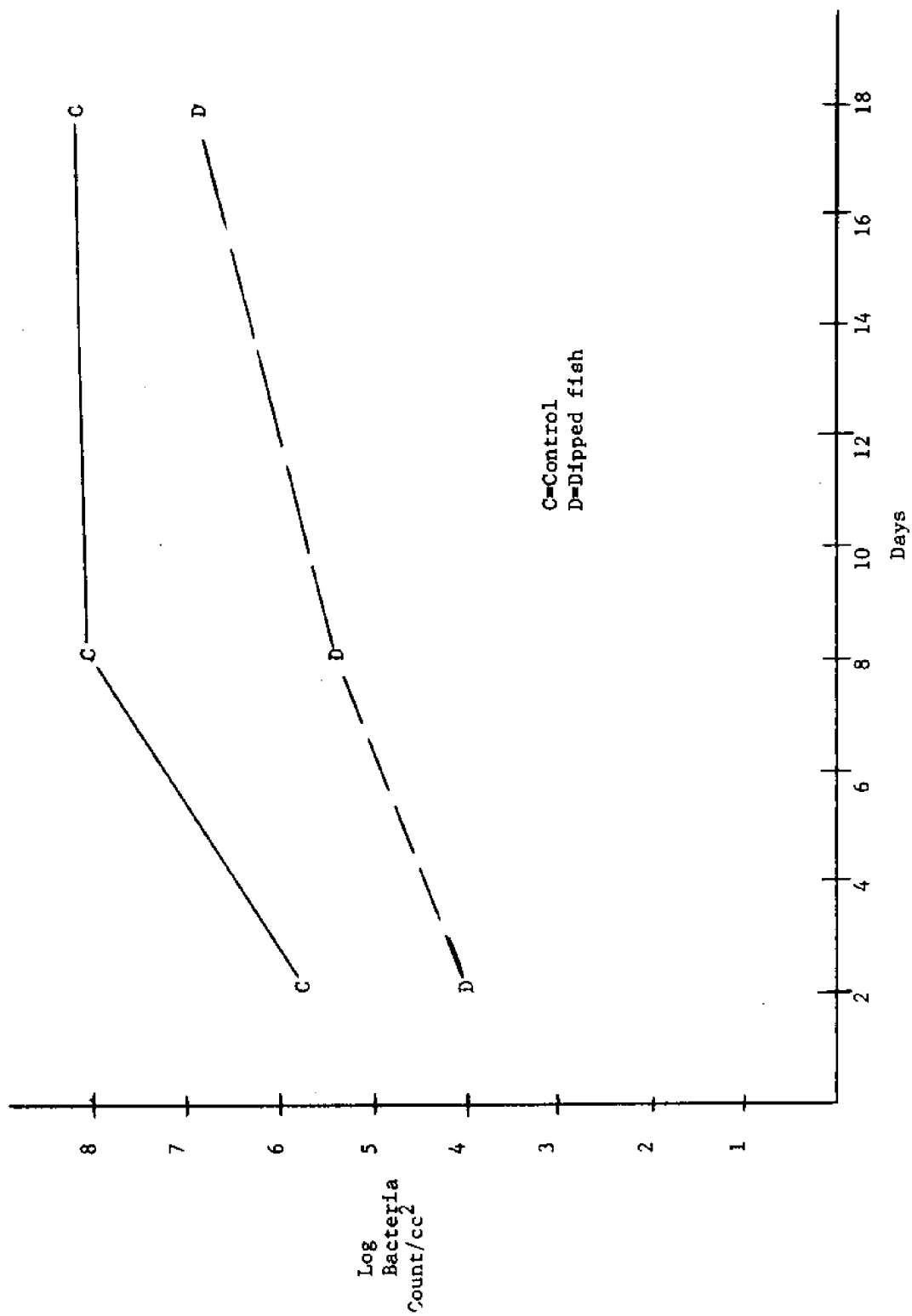


Fig. 2 Mean total microbial surface counts from the "belly" linings of iced red snapper.

HEAT RESISTANCE OF SALMONELLA WELTEVREDEN IN BROWN SHRIMP HOMOGENATE

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ABSTRACT

The heat resistance of Salmonella weltevreden in brown shrimp homogenate was studied by the thermal death time (TDT) tube method. Correction of exposure time for thermal lag and lethality during lag was made by the graphic method. The TDT curve gave a z value of 16.7°F (9.3°C). D -values, in minutes, calculated from combined data of replicate experiments by Schmidt's probability method, were 0.68 at 140°F (60°C), 0.61 at 142.5°F (61.4°C), and 0.38 at 145°F (62.8°C). The slope, z , of a decimal reduction curve was 19.8°F (11.0°C). The slopes of both the TDT and decimal reduction curves, 16.7 and 19.8°F, respectively, are much flatter than those usually reported for salmonellae, i.e. 7 to 12°F.

INTRODUCTION

Epidemiological investigations have demonstrated that shrimp may serve as vehicles for the transmission of salmonellae to humans. The U.S. Food and Drug Administration (FDA) routinely samples fresh-frozen shrimp for salmonellae. Approximately 200 salmonellae isolates per year were recovered by FDA from 1980 to 1982. The most frequently isolated serovar has been Salmonella weltevreden (9). When contaminated shrimp are discovered, FDA may take several courses of action: The shrimp may be destroyed, returned to the country of origin, or reconditioned to bring them into compliance. Ordinary cooking times and temperatures generally are considered adequate to kill salmonellae in foods of high moisture content. In many cases salmonellae-contaminated foods can be made safe by thermal processing without significantly impairing food quality.

The purpose of this study is to determine the time-temperature parameters for the thermal reconditioning of shrimp contaminated with S. weltevreden.

MATERIALS AND METHODS

Organisms and suspensions. S. weltevreden cultures were obtained from Richard Wagner, FDA, Minneapolis Center for Microbiological Investigations. These cultures had been isolated from frozen shrimp imported from India. Stock cultures were maintained on trypticase soy

agar (TSA) (Difco) slants; working cultures were prepared by transfer of stock cultures to tubes containing 10 ml of brain heart infusion broth (BHIB) (Difco). An inoculum was prepared by inoculating from the working culture to a screw-capped centrifuge tube containing 100 ml of BHIB. Stock and working cultures and inocula were incubated 24 ± 2 hours at 37°C . Cells were harvested by centrifugation and washing twice with sterile phosphate buffered saline (3). The organisms were resuspended in sufficient phosphate buffer to give a cell concentration of 2×10^8 colony forming units (CFU)/ml as determined by absorbance measurements (Baush and Lomb, Spectronic 20). Inoculum density was confirmed by enumeration by the standard plate count method.

Shrimp homogenate. Shrimp were harvested locally, headed, peeled and frozen in 700-800 g portions at -18°C until use. The shrimp were thawed in a microwave oven at low power and homogenized in a Waring commercial food processor to a smooth paste (ca. 2 min.). Sufficient inoculum was added to give a theoretical density of 1×10^6 CFU/g. The inoculated shrimp paste was rehomogenized for an additional 2 minutes to give even distribution of inoculum. Standard plate counts were made on 1 g portions of uninoculated and inoculated pastes.

Experimental procedures. The thermal resistance of *S. weltevreden* was determined by the thermal death time (TDT) tube-end point method (6). At least four replicate experiments were conducted at each of three temperatures, 140 , 142.5 and 145°F (60 , 61.4 and 62.8°C , respectively). Each experiment was designed to give a series of 10 exposure times per temperature with 10 TDT tubes per time so that a gradation in the number of tubes positive for *S. weltevreden* survival would occur between the last time at which all were positive and the first time at which all were negative.

For each replicate experiment 110 borosilicate TDT tubes (10×75 mm) were filled with 1.0 ± 0.1 g of inoculated shrimp paste by the grease gun technique (6). The tubes were immediately flame-sealed in an oxyacetylene flame. The sealed tubes were bundled into groups of five, tagged for identification, and weighted with a lead sinker to assure submersion, and held for at least 10 minutes in an ice bath until temperatures were uniform. All TDT experiments were conducted within 1.5 hours of tube preparation. The TDT tubes were dropped into a 44 liter hot water bath maintained at 140°F (60°C), 142.5°F (61.4°C), or 145°F (62.8°C), $\pm 0.1^{\circ}\text{F}$ (0.06°C) in groups of 10. All tubes were removed simultaneously at the end of treatment and immediately cooled in an ice bath. Ten tubes containing uninoculated paste served as controls with no treatment. Experimental and control tubes were opened aseptically within 1 hour of treatment. The contents of each tube were transferred into 10 ml of lactose broth (Difco) for preenrichment. All incubations were at 37°C . At 48 and 72 hours 1 ml of each preenrichment culture was transferred to 10 ml of tetrathionate broth

(Difco) and incubated for 24 hours. A 3 mm loopful from each tetrathionate tube was streaked on Hektoen enteric agar (Difco) and incubated 24 hours. Suspect colonies were transferred to triple sugar iron (TSI) agar (Difco) and lysine iron agar (LIA) (Difco) and incubated 24 hours. Presumptive positives were confirmed by API 20E and serological testing. If any control tubes produced typical colonies on the agar, the entire replicate was invalidated. Results were recorded as "survived" (+) or "killed" (-).

Calculations. Heat penetration rates were recorded from a copper-constantan thermocouple (Honeywell Inc.) placed in the geometric center of the 1 g portion of shrimp in a TDT tube. Replicate heat penetration studies were conducted at each temperature with four thermocouples used in each replicate. Exposure times for thermal lag and lethality were corrected by the method of Anellis (1) using data from heat penetration studies showing the slowest heating and cooling rates at each temperature. The corrected times for the last exposure time showing survival and the first interval with no survivors for all replicates at each temperature were plotted separately on semilogarithmic paper with time on the logarithmic axis and temperature on the arithmetic axis. The TDT curve was then drawn as described by Townsend *et al* (8) above all points representing survivors and below as many destruction points as possible. Decimal reduction times (D-values) were calculated from the corrected TDT data from combined replicates by Schmidt's probability method (5). The decimal reduction curve was fitted by least squares regression analysis and plotted on semilogarithmic paper along with the TDT curve. The slopes or z-values of the TDT and decimal reduction curves represent the number of °F required for the curve to traverse 1 log cycle.

RESULTS

Cumulated TDT data from each replicate experiment, corrected for thermal lag and lethality occurring during heating and cooling, are given in Table 1. At least three time intervals showing no survivors after the last exposure time showing survivors are reported for each temperature. This provides assurance that the survival endpoints are not the result of skips. Survival and no survival endpoints are plotted in Figure 1 to give a TDT curve with F_{140} of 6.25 minutes and z of 16.7°F (9.3°C). Average inoculum levels for the four replicates at 140, 142.5 and 145°F were 3.7×10^5 , 2.7×10^5 and 3.1×10^5 CFU per/g, respectively. Decimal reduction times (D-values), in minutes, (and 95% confidence limits) at 140, 142.5, and 145°F were, respectively, .68 (.65-.71), .61 (.58-.64), and .38 (.36-.40). These data are also plotted in Figure 1, and least squares regression analysis was used to draw a decimal reduction curve with a slope, z, of 19.8°F (11.0°C). The decimal reduction curve, frequently called a "phantom TDT curve" (2), for a particular organism is theoretically independent of the density of organisms and may be extrapolated outside the range of

Table 1. Cumulated TDT from four replicate experiments at each of three temperatures.

Temp. °F	Time (Min.)		tested	No. of Tubes	
	uncorrected	corrected		positive	negative
140.0	3.0	1.4	40	38	2
	4.0	2.4	40	38	2
	5.0	3.4	40	27	13
	6.0	4.4	40	16	24
	6.5	4.9	40	6	34
	7.0	5.4	40	5	35
	7.5	5.9	40	1	39
	8.0	6.4	40	0	40
	9.0	7.4	40	0	40
	10.0	8.4	40	0	40
142.5	3.0	1.4	33	33	0
	4.0	2.4	34	27	7
	4.5	2.9	38	25	13
	5.0	3.4	40	20	20
	5.5	3.9	40	17	23
	6.0	4.4	40	12	28
	6.5	4.9	40	0	40
	7.0	5.4	40	0	40
	7.5	5.9	40	0	40
	8.0	6.4	40	0	40
145.0	2.0	0.3	40	39	1
	2.5	0.8	40	40	0
	3.0	1.3	40	36	4
	3.5	1.8	40	32	8
	4.0	2.3	40	15	25
	4.5	2.8	40	4	36
	5.0	3.3	40	0	40
	6.0	4.3	40	0	40
	7.0	5.3	40	0	40
	8.0	6.3	40	0	40

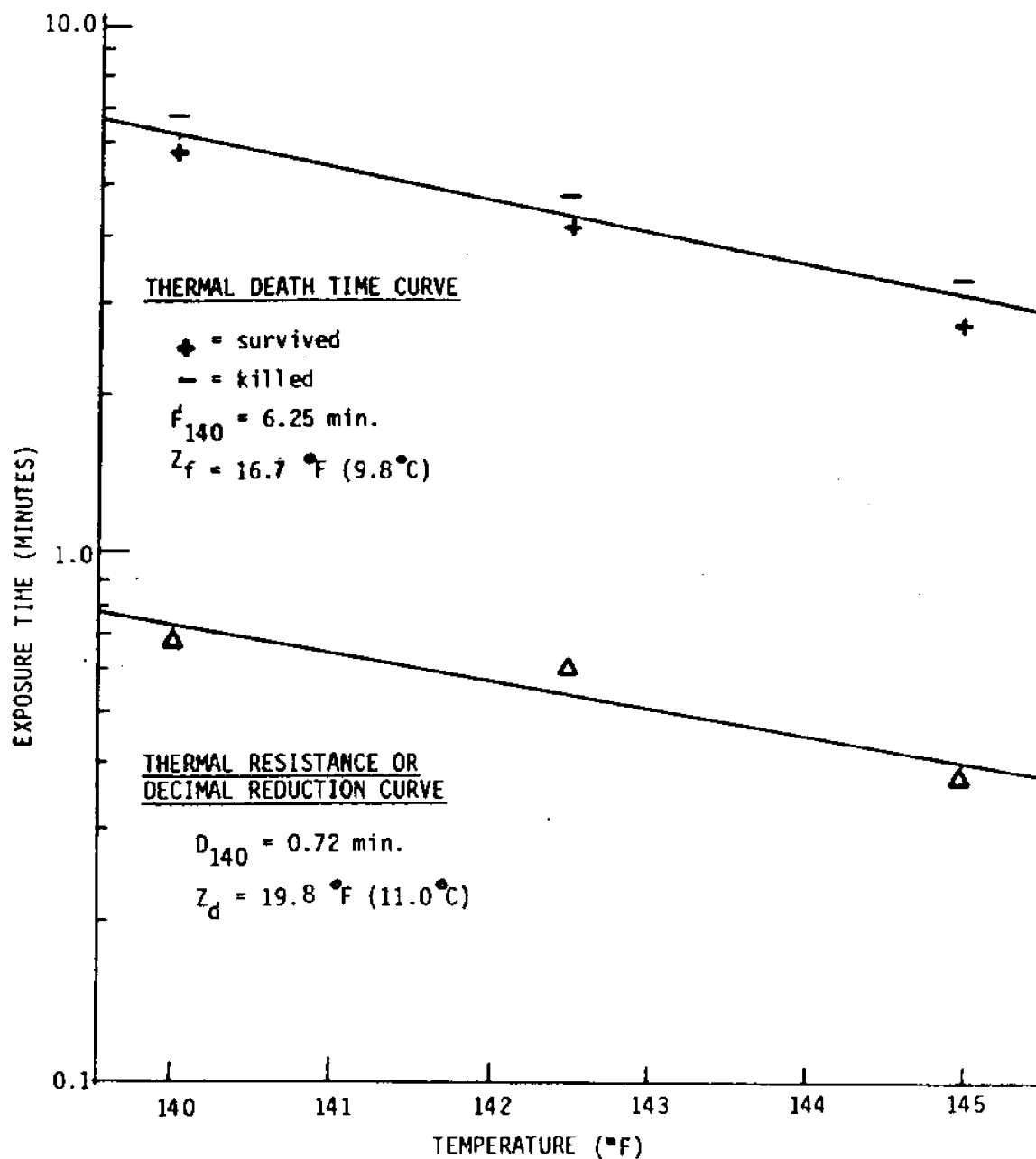


Figure 1. Thermal death time (TDT) and thermal resistance ("phantom TDT") curves for Salmonella weltevreden in shrimp homogenate.

temperature tested. Furthermore, its slope, z , can be assumed to be constant regardless of the test substrate or menstruum (7).

Thermal resistance studies frequently use 140°F as a reference temperature for comparison of decimal reduction times and are designated as D_{140} values. In this study we found the D_{140} for S. weltevreden to be 0.72 minutes, commonplace among D_{140} values reported for other salmonellae. The z values, 16.7 and 19.8°F, derived in this study for S. weltevreden are notable, since z values for salmonellae normally range from 7 to 12°F. A z of 10°F is generally accepted for vegetative bacteria including the salmonellae in any medium. The significance of the departure of z values for S. weltevreden from accepted z values is in the calculation of heat processing times.

DISCUSSION

In thermal processing the 12D concept is advocated to achieve protection from botulism (4). This concept is based upon the principle that foods should receive sufficient thermal processing to reduce the population of Clostridium botulism spores through 12 log cycles. For pasteurization or reconditioning of food products, 6D or 7D processing is generally practical. Using $D_{140} = 0.7$ minutes as a common reference point, 6D process equivalents for S. weltevreden were calculated for z values of 10°F and 18°F (approximating the average of this study) and plotted in Figure 2. The effect of the higher z for S. weltevreden is readily apparent, i.e., significantly longer equivalent processing times are required.

The use of $z = 10^\circ\text{F}$ for the thermal processing of low-acid foods has proven effective. S. weltevreden, the most common salmonellae isolated from shrimp, has a z of 16.7°F to 19.8°F. A z of 16.7°F to 19.8°F requires longer processing times than a z of 10°F at temperatures greater than 140°F. Thus, consideration should be given to using a z of 16.7°F to 19.8°F in designing any thermal reconditioning process for shrimp.

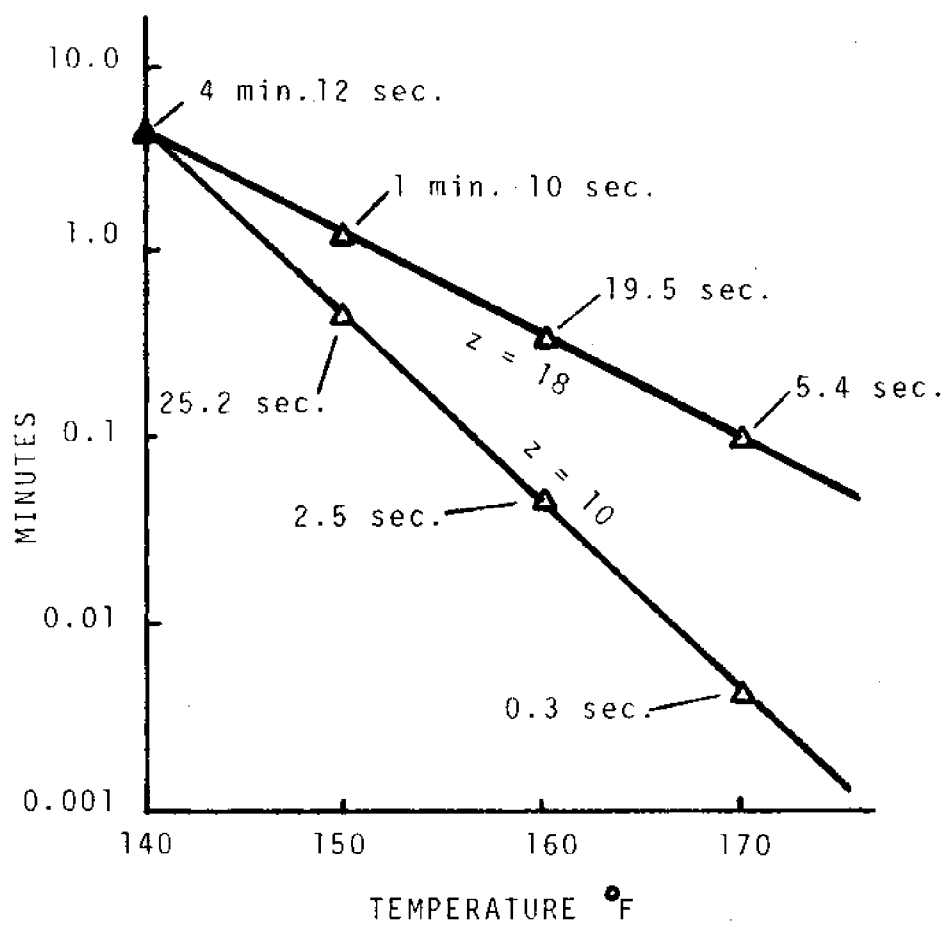


Figure 2. 6D Process Equivalents; $D = 0.7$ min. and z of 10 and 18.

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THERMAL PROCESS STUDIES OF ALLIGATOR MEAT

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INTRODUCTION

The American alligator (Alligator mississippiensis) is a common resident of the southeastern United States and is extremely abundant in Louisiana and Florida. Because of sound management practices and enforcement by the Louisiana Department of Wildlife and Fisheries, alligator populations were sufficiently high in Louisiana to permit a trial controlled 30 day harvest program in 1972. This controlled 30 day harvest continues today with approximately 20,000 animals taken from wild stocks. The wild harvest takes place in September for management reasons. The initial purpose of the 1972 harvest was for hide production. The resulting skinned carcasses were generally discarded or used only for personal consumption by the trapper since selling or trading the meat was illegal. In 1982, legislative changes were enacted that legalized the commercialization of meat parts resulting from legal harvest. Estimates place the total amount of available alligator meat in excess of 1,000,000 pounds.

Although studies have been completed on basic nutritional qualities of alligator meat (1), a characterization of the various cuts of meat and yield data (2,3,4), there has been little work done on the various methods of preservation. In view of the fact that there has been interest from commercial processors on recommended methods for heat processing alligator meat, an initial study was undertaken to examine the basic characteristics of thermal processed alligator meat.

METHODS

Samples

Several alligators of varying lengths and weights were captured by Louisiana Wildlife and Fisheries specialist at Rockefeller Wildlife Preserve at Grand Chenier, Louisiana. The alligators were slaughtered and butchered according to procedures recommended by Louisiana Food and Drug. After slaughter, the meat was bagged and held on ice during transport to the Department of Food Science at Louisiana State University, Baton Rouge, Louisiana. Upon arrival, the meat was trimmed of excess fat and all bone, sealed in plastic freezer bags and block frozen at -20°F . The meat packs were stored at -20°F until processed.

Process Determination

The alligator meat was placed at refrigerated temperatures ($35-40^{\circ}\text{F}$) and thawed 24 hours prior to processing. The raw meat was diced into chunks and hand packed into thirty 307 x 113 cans. One-third of the cans were dry-pack processed, one-third was water packed and one-third brine packed in 1% food grade NaCl. Thermal process determination was accomplished using five cans outfitted with thermocouples. The cans were placed in various locations within the retort. The cans with the thermocouples were connected to an Omega Model 250 Data Logger to monitor the process. The information from the Data Logger was used to determine lethalties and adequacy of process.

The raw packed product was canned using dry, 1% salt brine and tap water treatments. The process used was the same used for canned tuna and salmon, 1 hour at 250°F to register. The lethality desired was 40. This was met in all three treatments. This value was equivalent to canned tuna and salmon.

Texture

Instrumental texture characteristics of the three processed meat samples were determined using an Instron Universal Testing Device equipped with a 10 blade shear cell. The samples peak shear force was determined and reported as kg force/g sample.

Color

Color of the samples was monitored using the HunterLab Color Difference meter. The L, a, and b readings were reported. Readings were taken prior to canning and one month after processing.

RESULTS AND DISCUSSION

Texture

The Instron values as determined using the Instron Universal Testing Device ranged from 14.6 kg force/g sample (dry pack) to 19.7 kg force/g sample (water pack) (Figure 1). This was not expected since other dry packed products such as dog food and salmon tend to become firmer with processing. It would be expected that the water packed product would be very soft following processing under the conditions of this study. However, as with the dry pack

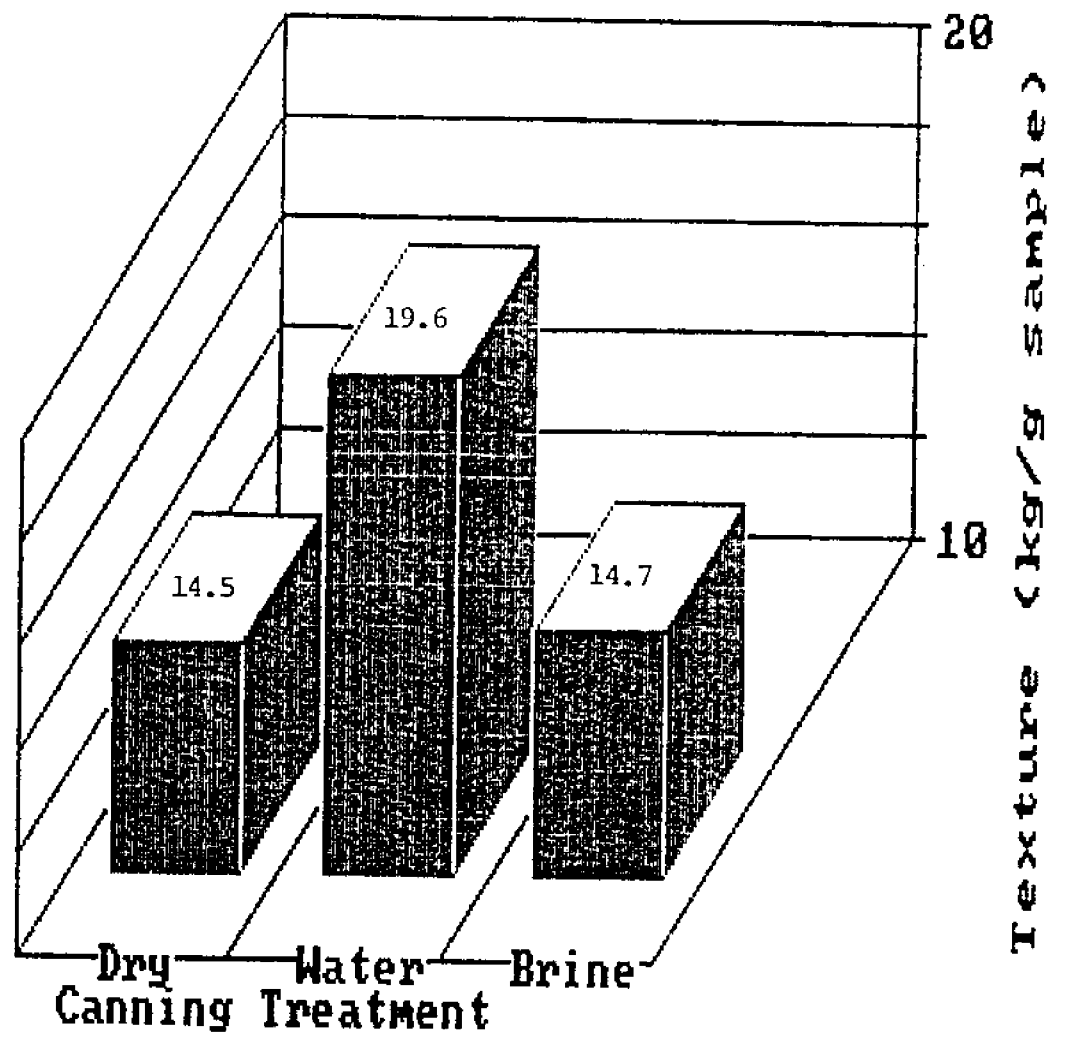


Figure 1--Instron texture measurements for canned alligator meat.

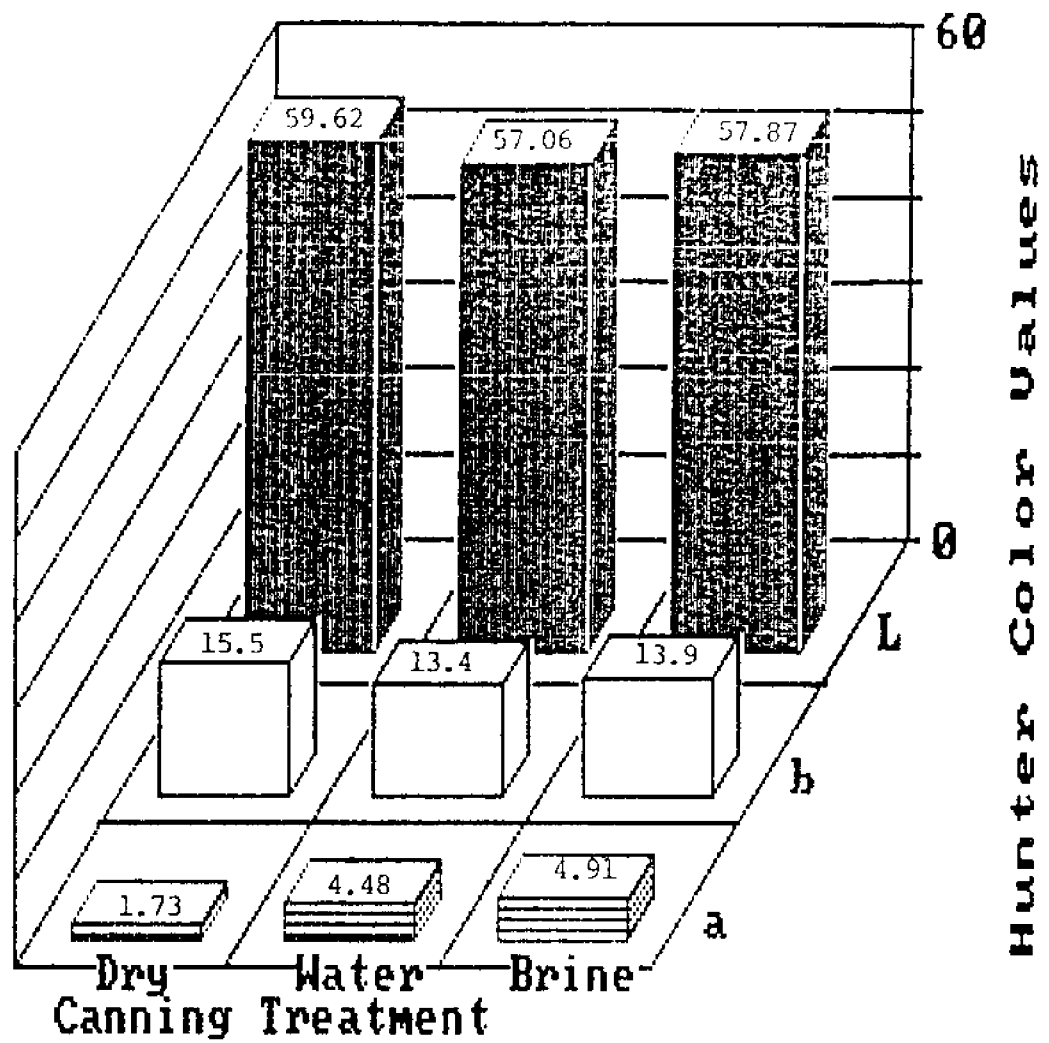


Figure 2--Hunter color difference values for canned alligator meat.

the opposite occurred. The 1% salt brine should have been slightly less firm than the dry pack but firmer than the water pack. This was not observed. One factor which may have contributed to the above was the fat content and location in the samples. No segregation of lean and fat samples was made and fat pockets may have contributed to the texture differences.

Color

Alligator meat is somewhat similar to pork in appearance and texture. The raw product is pink to white in color and has externally layered fat. The cooked product tends to be light brown with no pink or red present. The color values are presented in Figure 2 and the L values indicate lightness, the a values represent red and b values represent yellow. The dry packed product was the lightest of the sample, but was not significantly different from the other treatments. The a and b values also did not show any significant differences in values between treatments. The water and brine packed products maintained the pink color as compared to the dry pack product.

FUTURE CONSIDERATIONS

Sensory analysis and a study of pre-cooked meat are presently being undertaken. The pre-cooking under-live steam could remove the "gamey" flavor associated with alligator. This process could possibly improve the texture and color characteristics of the alligator. Finally, the pre-cooking may decrease the process time.

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UPTAKE AND FATE OF BACTERIA BY SHELLFISH IN A LABORATORY DEPURATION SYSTEM

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INTRODUCTION

Shellfish are filter feeders and pump large volumes of sea water. Thus, shellfish may accumulate and concentrate bacteria or other contaminants, if they are present in their environment. Depuration is defined as the natural process of purification by which the shellfish cleanse themselves. In depuration, contaminated shellfish are placed in "clean" sea water and the accumulated pollutants are eliminated from the organism by mechanisms which are not well-known. Although depuration of shellfish has been employed for a number of years (7), the time course of response of the shellfish under varying environmental circumstances and with various suites of bacteria, particularly pathogens and other bacterial loads, has not been thoroughly studied. This investigation dealt with the depuration of bacteria (non-O1 Vibrio cholerae and V. vulnificus) from oysters collected from the waters of Apalachicola Bay and clams from Tampa Bay. In general, the methods and principles described in this project could hold true for other shellfish, other contaminants and other estuaries.

Depuration in many areas of the United States is a necessity because of the increased number of persons living within the coastal zone. In addition, waste-waters from concentrated population centers have significantly degraded the water quality in many oyster and clam beds (6). As a result, increasing acreages of the best oyster growing bottoms in the United States and in Florida are classified as restricted from shellfish culture (2,8). Furthermore, the lack of correlation between F.D.A. fecal coliform standards and potentially pathogenic Vibrios (2,8) has caused many problems for the F.D.A. Most evidence indicates that the majority of these potentially pathogenic Vibrios are of non fecal origin and naturally occur in most of the oyster beds in the United States (3,5). In order for these shellfish to be used, they first must be cleaned or caused to cleanse themselves of potentially pathogenic Vibrios and other particulate materials.

Laws relating to the use of the shellfish from restricted areas vary from state to state, but most allow sale of the shellfish if they are relayed into approved waters for a specified period of time. However, relaying oysters is expensive and it is seldom possible to reharvest more than 80% of the crop. Therefore, depuration under controlled conditions offers an attractive alternative to relaying in natural waters.

The basic requirements of efficient depuration are few and simple. In most cases, sea water is taken from a nearby estuary, disinfected by ultraviolet light, and recirculated through a holding "depuration" tank (7). Similarly, shellfish are taken from nearby growing areas, washed and placed in the depuration tank for a prescribed period of time. Once the purification has been achieved, the oysters are sent to market.

MATERIALS AND METHODS

During 1983 and 1984, approximately 600 specimens of oysters (Crassostrea virginica) were collected at Apalachicola Bay from both approved and unapproved waters. Oysters were marked appropriately so mixing did not occur.

More than five hundred specimens of clams (Mercenaria campechiensis) of approximately the same size (shell length 8-10 cm) were collected off the south end of the Sunshine Skyway Bridge (Terra Ceia, FL.). The clams were transported in coolers containing water from the collection site and placed in holding tanks (55 gal. aquaria) containing water of the same salinity. Both the clams and oysters were maintained in the holding tanks for 2-3 days to allow for adequate acclimatization to laboratory conditions. During this period the clams were fed a daily ratio of phytoplankton culture consisting mainly of Chlorella and Chlamydomonas. The culture had an average density of 1×10^6 cells/ml of which 100 ml per clam was added daily by a slow drip (1 drop/sec) infusion into the holding tanks.

Phytoplankton consisting of Chlorella and Chlamydomonas was maintained on agar plates containing sea salts, F/2 media, antibiotics and fungicide. The algae was cultured in two liter flasks using F/2 media with mild aeration and 24 hour fluorescent lighting. Every 48 hours aliquots were withdrawn from the culture flasks and replaced with fresh F/2 media. Algae counts were determined by using a Neubauer cell counting chamber.

Escherichia coli, non-01 Vibrio cholerae and V. vulnificus were grown on brain-heart infusion (BHI) agar overnight at 37°C. Isolated colonies were scraped off the plate and resuspended in phosphate buffered saline (PBS). This suspension's optical density was read spectrophotometrically and adjusted to 10^6 cells per milliliter of Vibrios. Viable counts were confirmed by calculating the number of colony forming units on thiosulfate citrate bile salts (TCBS) agar.

Three to five specimens (100 grams of meat) of C. virginica or M. campechiensis in each experiment were used for background controls. The oyster and clams were scrubbed under running tap water, then opened with an alcohol flamed oyster knife. The weighed individuals were placed in preweighed Waring blender jars. Equal weight/volume of phosphate buffered saline (pH 7.4) was added. The resulting crude homogenate was then diluted with peptone water from 10^{-1} to 10^{-6} . These dilutions were inoculated in a 3-tube MPN series containing alkaline peptone and incubated for 8 to 10 hours at 37°C. Positive cloudy tubes were recorded, then streaked on to TCBS agar plates for confirmation of either non-O1 V. cholerae or V. vulnificus.

Seawater samples were diluted in peptone water or phosphate buffered saline (pH 7.4). Dilutions were inoculated into alkaline peptone (1 ml in 9 ml) 3-tube series. Incubation and processing of positive tubes followed established techniques as described above (1).

The experiments dealing with the uptake, retention and fate of non-O1 V. cholerae and V. vulnificus included numerous groups of 20-25 clams and oysters collected from Tampa Bay and Apalachicola Bay, respectively.

At the start of each experiment, the U.V. system was removed and the control clams and oysters were processed separately. One liter of algae and bacteria (either Escherichia coli, non-O1 Vibrio cholerae or V. vulnificus) was added to each aquarium, respectively. After adequate mixing in each tank, a seawater sample was taken and processed bacteriologically as previously described for the determination of E. coli, V. cholerae and V. vulnificus.

At predetermined timed intervals, oysters and clams were removed, rinsed with 70% ethanol, scrubbed with a brush under tap water and processed bacteriologically as previously described. Seawater samples were taken from each tank at the same time as the experimental clam, oysters and controls. As a result of these experiments the kinetics of the uptake, and the fate of both non-O1 V. cholerae and V. vulnificus were determined.

The experiments dealing with the effects of U.V. irradiation involved separate groups (20-25) of oysters and clams inoculated in a glass aquarium as described in the uptake, retention and fate experiments. The initial seawater Vibrio concentration was determined using established techniques (9). The groups of inoculated clams and oysters were then placed into 2 separate tanks. Seawater in Tank Number 1 was recirculating without U.V. treatment. Seawater in Tank Number 2 was recirculating with U.V. treatment. A control tank contained only seawater and bacteria. After 24, 48, and 72 hours, seawater, oysters and clams were processed bacteriologically for the determination of the presence of E. coli and Vibrios as previously described above.

RESULTS AND DISCUSSION

Experimental Depuration of Fecal Coliforms and Vibrios

Oysters and clams were exposed to known quantities of algae and bacteria and allowed to accumulate or concentrate internal levels of the bacteria (Tables 1, 2 and 3). These experiments were critical to all further experiments in that a method of inoculation had to be simple, precise and efficient. All three of these criteria were met by the introduction of bacteria with algae. Past experiments dealing with the uptake of bacteria by shellfish resulted in equilibrium of equal numbers of bacteria in both seawater and shellfish. Our experiments resulted in a concentration of bacteria inside both oysters and clams rather than an equilibrium condition attained by other workers.

Specifically, peak numbers of non-01 V. cholerae and V. vulnificus were concentrated in the clam at 3 and 6 hours, respectively. In addition, peak numbers of V. cholerae and V. vulnificus were concentrated by the oyster at 2 and 4 hours, respectively (Tables 1, 2 and 3).

The distribution of Vibrio vulnificus and non-01 V. cholerae in selected tissues of the clam were determined (Tables 4 and 5). After inoculation with either V. vulnificus or non-01 V. cholerae, groups of clams were removed at 60 and 90 minutes, and the clam tissue dissected into the digestive gland, gonadal area, mantle, and gill. Hemolymph was also collected. The largest numbers of both non-01 V. cholerae and V. vulnificus were found in the digestive gland with the lowest numbers found in the hemolymph. As expected, the largest number of bacteria occurred in the digestive system where depuration would be effective. Although large numbers also were found in other tissues, they are easily destroyed by the bivalve defense system.

The effects of ultraviolet irradiation on the viability of non-01 V. cholerae, V. vulnificus, and E. coli were also determined. Table 5 shows the percent reduction of viable non-01 V. cholerae in recirculating seawater when exposed to ultraviolet irradiation for 2, 5, 24, and 48 hours. Essentially, 99.9% reduction occurred after only 2 hours exposure while essentially 100.0 was reduced after 5 hours (Table 6). This 100% reduction held for 24 and 48 hours of exposure.

Similarly, a rapid percent reduction of V. vulnificus and E. coli was observed. Specifically, 99.9% reduction of both V. vulnificus and E. coli was detected in the recirculation seawater after only 30 minutes of ultraviolet irradiation (Table 7 and 8).

Table 9 compares the State of Florida, Department of Natural Resources recommended values of flow rate, ultraviolet lamp wattage, pH, salinity, temperature, and turbidity with our experimental values. All listed values in our experiments are either equal to or exceed the State of Florida recommended values.

Table 1. The uptake of Vibrio vulnificus by the southern quahog, Mercenaria campechiensis.

Exposure Time (Hours)	M P N [*]	
	Seawater	Clam
t ₀	3.0	3.0
t ₃	2.3×10^5	2.3×10^4
t ₆	3.3×10^4	3.3×10^5
t ₂₄	9.3×10^5	3.6×10^4
t ₄₈	4.3×10^5	4.5×10^4

* All values (MPN) are expressed as numbers of V. vulnificus per 100 mls seawater or number V. vulnificus per 100 gm wet weight of clam tissue. Clams were exposed to 2.3×10^6 V. vulnificus per 100 mls of seawater.

Table 2. The uptake of Vibrio vulnificus by the eastern oyster, Crassostrea virginica.

Exposure Time (Hours)	M P N *	
	Seawater	Oyster
t 0	3.0	3.0
t 2	9.3×10^5	5×10^6
t 4	7.5×10^4	1.6×10^7
t 8	4.3×10^4	3.5×10^5

* All values (MPN) expressed as numbers per 100 mls of seawater or per 100 gm of oyster. Oysters were exposed to 1×10^6 V. vulnificus per 100 mls of seawater.

Table 3. The uptake of non-01 Vibrio cholerae by the southern quahog, Mercenaria campechiensis.

Exposure Time (Hours)	M P N [*]	
	Seawater	Clam
t ₀	3.0	3.0
t ₂	2.3×10^7	2.3×10^3
t ₈	2.3×10^7	2.3×10^5
t ₂₄	9.3×10^6	1.5×10^6
t ₄₈	4.3×10^3	9.3×10^6

* Most Probable Numbers (MPN) equals number of non-01 V. cholerae per 100 mls seawater or per 100 gm of clam. Clams were exposed to 4.3×10^7 non-01 V. cholerae per 100 mls of seawater.

Table 4. The distribution of Vibrio vulnificus in selected tissues from the southern quahog, Mercenaria campechiensis.

Exposure Time (Minutes)	M P N of Clam Tissue*				
	Digestive Gland	Gonadal Area	Mantle	Gill	Hemolymph
^t 0	3.0	3.0	3.0	3.0	3.0
^t 60	8.4×10^6	7.6×10^5	4.2×10^5	8.0×10^5	3.0×10^5
^t 90	6.2×10^6	3.4×10^5	2.2×10^5	8.0×10^5	2.5×10^5

* Background levels of V. vulnificus were 3 per 100 gm wet tissue weight. All values expressed as Most Probable Number (MPN) per 100 gm wet weight of tissue. Clams were exposed to 2.0×10^5 V. vulnificus per 100 mls of seawater.

Table 5. The distribution of non-O1 Vibrio cholerae in selected tissues from the southern quahog, Mercenaria campechiensis.

Exposure Time (Minutes)	M P N of Clam Tissue*				
	Digestive Gland	Gonadal Area	Mantle	Gill	Hemolymph
t 0	3.0	3.0	3.0	3.0	3.0
t 60	5×10^6	4×10^5	3×10^4	4×10^5	2×10^4
t 90	2.1×10^7	2×10^6	4×10^5	1×10^5	7×10^4

* Background levels of non-O1 V. cholerae were 3 per 100 gm wet tissue weight. All values (MPN) expressed as number of non-O1 V. cholerae per 100 gm wet weight of clam tissue. Clams were exposed to 4.3×10^7 non-O1 V. cholerae per 100 mls of seawater (30‰).

Table 6. The effects of ultraviolet irradiation on viability of non-01 Vibrio cholerae (MPN*) in recirculating seawater at timed intervals.

Treatment	Exposure Time (Hours)				
	0	2	5	24	48
Without U.V.	2.1×10^7	4.3×10^6	9.3×10^6	2.3×10^6	4.3×10^4
With U.V.	2.3×10^7	2.3×10^2	< 3.0	< 3.0	< 3.0
Percent reduction of viable <u>V. vulnificus</u>	-	99.9	100	100	100

* All values are expressed as Most Probable Number (MPN) of non-01 V. cholerae per 100 mls of seawater.

Table 7. The effects of ultraviolet irradiation on viability of Vibrio vulnificus (MPN*) in recirculating seawater at timed intervals.

Treatment	Length of Exposure (Hours)						
	0	0.5	1	2	3	4	6
Without U.V.	3.3×10^2	6.8×10^5	8.4×10^4	5.9×10^5	1.5×10^6	2.6×10^6	4.3×10^6
With U.V.	3.3×10^6	2.3^2	3.3^2	0.65^2	2.3^2	3.3^2	2.3^2
Percent reduction of viable <u>V. vulnificus</u>	-	99.97	99.61	99.99	99.99	99.99	99.99
							99.98
							1.6×10^7
							33^2

* All values are expressed as Most Probable Number (MPN) of V. vulnificus per 100 mls of seawater.

Table 8. The effects of ultraviolet irradiation on viability of Escherichia coli (MPN*) in recirculating seawater at timed intervals.

Treatment	Length of Exposure (Hours)					
	0	0.5	2	9	24	48
Without U.V.	9.3×10^6	1.5×10^7	2.3×10^6	9.3×10^5	2.3×10^5	4.3×10^4
With U.V.	9.3×10^6	2.3×10^3	2.1×10^3	<3	4.3×10^2	<27.0
Percent re- duction of viable <u>V.</u> <u>vulnificus</u>	-	99.9	99.9	99.9	99.8	99.9

* All values are expressed as Most Probable Number (MPN) of E. coli per 100 mls of seawater. Each value represents a mean of at least two determinations.

The effects of ultraviolet irradiated recirculating seawater upon the depuration of non-01 Vibrio cholerae and V. vulnificus in clams are shown in Tables 10 and 11, respectively. After 24 hours of ultraviolet irradiation, seawater containing non-01 Vibrio cholerae and V. vulnificus decreased significantly (99.7 and 99.9%, respectively) when compared to seawater which was not being treated with ultraviolet light. In addition, differences were detected between clams or oysters challenged with known amounts of non-01 V. cholerae and V. vulnificus placed in identical tanks in either recirculating seawater or recirculating ultraviolet-treated seawater. Specifically, results of these experiments are shown in Tables 10 and 11 and reveal a significant decrease (99.9 and 96.2%) in Vibrio content of individuals treated with U.V. irradiated recirculated seawater when compared to those clams and oysters which were exposed to seawater without U.V. treatment for 24 hours. These percent reductions held for 72 hours for non-01 V. cholerae but fluctuated for V. vulnificus at 48 hours.

The effects of ultraviolet irradiated recirculating seawater upon the depuration of non-01 V. cholerae in oysters are shown in Table 12. Results revealed that a 99.6% reduction in the numbers of non-01 V. cholerae after 24 hours of treatment and V. cholerae was essentially undetectable after 48 hours. After 72 hours low numbers were found only in the U.V. seawater system. Reasons for this are unknown.

The effects of U.V. irradiated seawater upon naturally acquired fecal coliforms are shown in Table 13. After 48 hours of recirculating U.V. treated seawater the fecal coliform level in the oyster meat was reduced approximately 18.7 times when compared to oysters placed in similar recirculating seawater without U.V. treatment (Table 13).

However, when freshly harvested oysters which contained naturally acquired vibrios were treated with U.V. recirculating seawater for 24 hours, the numbers of vibrios increased. Only after 96 hours, did the numbers decrease and then the vibrios were never completely eliminated (Table 14). Greenberg, *et al.* (6) reported a similar finding with clams inoculated with laboratory grown vibrios.

Reasons for the differences between the depuration of naturally infected and laboratory infected shellfish are unclear. One possible reason may be differences in acclimatization and pumping rate of the shellfish. In all laboratory infected experiments, shellfish were acclimated whereas the naturally infected shellfish were not. The non-acclimated shellfish situation is theoretically closer to a normal depuration situation. That is to say, the shellfish would be placed in seawater and not allowed to acclimate to the conditions. It is possible that the naturally acquired vibrios possess different characteristics than the laboratory reared vibrios and, consequently, can remain in the digestive tract for longer periods.

The effects of salinity on 24 and 48 hours of U.V. assisted depuration of fecal coliform in the oyster was tested at 15, 20, 25, and 35‰. The percent reduction of fecal coliforms was greatest at 20‰ for 24 hours and 25‰ for 48 hours (Table 15). These results are in

Table 9. Recommended and experimental environmental parameters for depuration systems.

Parameter	Recommended ¹	Experimental
Flow Rate	1 gal/min/bushel	1-3 gal/min
U.V. Wattage	bactericidal	15 mwatts-sec/cm ²
pH	7.0 - 8.4	8.2
Salinity	suitable	32 ppt
Temperature	suitable	25° C
Turbidity	0-20 JTU	2.0 JTU

¹ State of Florida, Department of Natural Resources, Chapters 16B-42 Permit.

Table 10. The effects of ultraviolet irradiation on the depuration of non-01 Vibrio cholerae in Mercenaria campechiensis in recirculating seawater at timed intervals.

Treatment	Exposure Time (Hours)		
	M P N [*]		
	24	48	72
Seawater without U.V.	9.3×10^2	2.3×10^3	< 3.0
Seawater with U.V.	<3.0	<3.0	< 3.0
Percent reduction of <u>V. cholerae</u> in seawater	99.7	99.9	0
Clam without U.V.	2.3×10^4	9.3×10^2	$< 2.3 \times 10^3$
Clam with U.V.	<3.0	<3.0	<3.0
Percent reduction of <u>V. cholerae</u> in clams	99.9	99.7	99.8

* MPN expressed per 100 ml seawater or per 100 gm wet weight clam. Twenty four clams were exposed to 2.3×10^7 non-01 V.cholerae per 100 mls of seawater.

Table 11. The effects of recirculating ultraviolet irradiated seawater on the elimination of Vibrio vulnificus in the southern quahog, Mercenaria campechiensis.

Treatment	Exposure Time (Hours)		
	M P N [*]		
	24	48	72
Seawater without U.V.	2.3×10^3	<3.0	<3.0
Seawater with U.V.	<3.0	<3.0	<3.0
Percent reduction of <u>V. vulnificus</u> in seawater	99.8	0	0
Clam with U.V.	15.1×10^2	9.1×10^2	<3.0
Clam without U.V.	4.0×10^4	1.7×10^3	1.4×10^2
Percent reduction of <u>V. vulnificus</u> in clams	96.2	44.8	97.8

* All values are expressed as Most Probable Numbers (MPN) of Vibrio vulnificus per 100 ml of seawater or 100 gm of clam meat. Clams were exposed to 2.3×10^6 V. vulnificus per 100 mls of seawater for 6 hours.

Table 12. The effect of ultraviolet irradiation of recirculating seawater on the depuration of non-O1 Vibrio cholerae from oysters.

Treatment	Exposure Time (Hours)		
	M P N [*]		
	24	48	72
Oysters with U.V.	<3	<3	<3
Oysters without U.V.	1.2×10^3	<3	<3
Percent reduction	>99.8	0	0
Seawater with U.V.	>3	>3	>3
Seawater without U.V.	>3	>3	>3
Percent reduction	0	0	0

* MPN is expressed per 100 gm of oyster tissue or 100 ml seawater. Oysters were exposed to 4×10^4 CFU of non-O1 V. cholerae for 4 hours.

Table 13. The effects of recirculating ultraviolet irradiated seawater on depuration of fecal coliforms acquired by oysters.

Treatment	Exposure Time (Hours)		
	M P N [*]		
	0	48	96
Oysters without U.V.	7.5×10^3	4.3×10^4	< 3.0
Oysters with U.V.	7.5×10^3	2.3×10^3	< 3.0
Seawater without U.V.	< 3.0	≤ 23	< 3.0
Seawater with U.V.	< 3.0	≤ 4	< 3.0

* All values are expressed as Most Probable Numbers (MPN) of fecal coliforms per 100 mls of seawater or 100 gm of oyster meat.

Table 14. The effects of recirculating ultraviolet irradiated seawater on depuration of total *Vibrio*-like organisms from naturally infected oysters.

Treatment	Exposure Time (Hours)		
	M P N [*]		
	0	24	96
Oysters without U.V.	9.3×10^4	4.3×10^7	2.3×10^4
Oysters with U.V.	9.3×10^4	4.3×10^5	9.3×10^2
Seawater without U.V.	<3.0	2.3×10^4	4.3×10^4
Seawater with U.V.	<3.0	2.3×10^3	9.0×10^1

* All values are expressed as Most Probable Numbers (MPN) of total *Vibrio* count per 100 ml of seawater or 100 gm of oyster meat.

Table 15. Effect of salinity on depuration of fecal coliform from oysters.

Salinity (‰)	Exposure Time (Hours)				
	0	24		48	
		% Reduction		% Reduction	
15	9.3×10^6 *	9.3×10^6	0	9.3×10^6	0
20	9.3×10^6	2.3×10^5	97.5	4.3×10^5	95.4
25	9.3×10^6	1.5×10^6	83.9	2.0×10^5	97.8
35	9.3×10^6	9.3×10^5	90.0	9.3×10^5	90

* Oysters were first exposed to *E. coli* for 2.5 hours, after which groups of 10 oysters were placed in 10 liters of seawater with pre-selected salinities (i.e., 15 ‰, 20 ‰, 25 ‰ and 35 ‰). Seawater was not recirculated. Following exposure, oysters contained a 9.3×10^6 MPN as measured by the A-1 method. All values represent MPN per 100 gm of tissue.

agreement with coliform survival rates reported by other workers (Cabelli and Heffernan, 1970).

In summary, results reported herein substantiate that low levels of enteric bacteria such as E. coli, non-O1 V. cholerae and V. vulnificus can be removed in clams and oysters in a depuration system. In addition, both non-O1 V. cholerae and V. vulnificus are killed rapidly in high numbers in seawater by ultraviolet irradiation. Acclimated shellfish containing high numbers of E. coli, non-O1 V. cholerae and V. vulnificus can be significantly reduced. However, non-acclimated shellfish containing high levels of fecal coliforms and Vibrio like species were not efficiently depurated in the suggested time frame. Reasons for these differences are unclear and further research monitoring the levels of Vibrio like species and fecal coliforms should be conducted at an actual depuration plant, using both clams and oysters.

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POSTHARVEST CHANGES IN THE MICROBIOLOGICAL QUALITY OF SHELLSTOCK LOUISIANA OYSTERS

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INTRODUCTION

In 1981-82, the demand for oysters increased on the East Coast and, for the first time, large numbers of Louisiana oysters were being harvested and transported there during the summer and fall. The year-round harvesting of oysters has been an important advance in the utilization of this seafood resource, and has provided steadier employment in the fishing and processing aspects of the industry.

The bacteriological quality of oysters is assessed, on the basis of two indicator systems. The aerobic plate count monitors product abuses, such as inadequate refrigeration or prolonged storage (2, 5, 6). Fecal coliform tests are used to indicate the sanitary quality and safety of oysters (1, 2, 5, 7). Oyster contamination with fecal coliforms is influenced by a number of factors, including water quality, temperature, and pH, and longevity of the microorganisms in the marine environment (3, 8). After harvest, fecal coliform levels usually did not increase, in studies of oysters from the East Coast and in the Chesapeake Bay areas (5). However, Gulf Coast oysters differ from this pattern, during warm weather (5, 6). Fecal coliform counts can increase considerably, between harvesting and arrival at the wholesale market, especially during the months of July, August, September, and October.

Concerns and questions over the multiplication of fecal coliforms in Louisiana oysters, have made it important to study the influences of commercial harvesting and transportation practices on fecal coliform levels. Critical observations of routine commercial practices were made, to recognize potential contamination and abuse, which might contribute to fecal coliform loads.

MATERIALS AND METHODS

Oysters were collected at various points during commercial harvesting, handling and transportation operations. Oyster samples were transported to the laboratory in ice, and scrubbed and shucked upon arrival. Samples were tested in accordance with the Compendium of Methods for the Microbiological Examination of Foods (2). Aerobic plate count, fecal coliforms, and E. coli were determined. Suspected E. coli colonies were identified by the API 20-E system.

RESULTS AND DISCUSSION

Oyster harvesting has changed little, over the past half-century. In Louisiana, most oyster harvesting is done by dredging. Typical oyster boats are wooden-hulled vessels with a wide foredeck. There is often a canvas canopy stretched over this working area. A winch system is centered ahead of the cabin, with roller arrangements on either side of the deck, to facilitate raising and lowering of dredges. The commercial oyster dredge is a rake-like device. Heavy tines protrude downward to scoop oysters into its basket. A dredge-load of oysters is hoisted on board and dumped onto the deck, where oysters are worked by hand. The oysters are culled, broken into "singles", and tossed into a pile on deck. From this point, they are measured into large burlap sacks, in lots of about one and one-half bushels. The sacks of oysters are stacked on deck, unrefrigerated, until the boat returns to dock.

Most warm-season oyster harvesting is now done on one-day fishing trips. Oyster boats usually leave the dock early in the morning, at or about daylight, proceed to the chosen oyster beds, and begin harvesting operations. The tendency is, to intensively harvest oysters from a small locale and abandon this site. The dredging operation may involve repeated passes in a bayou or ever-widening circles in an area of open water. Poles may be used to mark previous passes, if needed. Culling of dredge loads usually goes on continuously during the harvest operation. Intensively-harvested oyster beds require about two years to replenish themselves with marketable oysters.

Efforts were made to simulate the "real world" conditions of growing, harvesting, and handling of oysters, so that cause-and-effect studies could be conducted with the benefit of laboratory controls. However, there were variables affecting the microbiology, which could not be duplicated in the laboratory. These factors included such influences as vibrations in the truck, humidity, contact with sacks, and percolation of water, and probably other unknowns. Therefore, these studies were concentrated on field samplings, during commercial oystering operations.

Dockside oyster samples were examined, from the first and last sacks harvested on fishing trips. Harvesting and on-vessel handling influenced the microbiology of oysters (Table 1), with an overall trend toward more bacteria in the last sacks. Higher levels of bacteria in last-sack oysters may have come from an outside source, perhaps by their filter-feeding during harvest operations. Harvesting in confined areas leads to sediment suspension, which could have carried bacteria into feeding oysters. Oysters from the last sack seemed to have a muddy appearance, but there was no means to quantify or statistically substantiate this observation. Other variables, such as composition of the microflora, may also have influenced the bacterial numbers in oysters. During the warm season, bacterial multiplication in oysters may have led to greater increases in early catches, whereas cool weather

could have retarded this growth during the day.

Upon arrival at dockside, the sacks of oysters were loaded into trucks for transportation to processing plants. Refrigerated trucks are required for shipment of oysters to out-of-state processors, but short

Table 1. Microbiology of Harvesting

MONTH	AEROBIC PLATE COUNT/g		FECAL COLIFORMS/100g	
	First sack	Last sack	First sack	Last sack
March	4.1×10^2	1.5×10^3	330	220
April	4.1×10^2	2.2×10^3	20	1.t.20
May	1.5×10^4	7.5×10^3	94	49
June 5.2×10^3	4.6×10^3	50	220	
July 2.0×10^5	1.9×10^4	g.t.2400	7000	
August	1.0×10^6	g.t. 10^6	16000	16000
September	5.1×10^4	6.8×10^5	94000	70000

g.t., l.t.: greater than, less than.

hauls are often made with flatbed trucks. A recent ruling by Louisiana state public health officials now requires that refrigerated trucks be used for in-state oyster transportation during warm weather, when travel time is greater than 4 h.

For the studies of transportation, oyster samples were taken at dockside, during transport, and upon arrival at the destination. Figure 1 demonstrates the increases in fecal coliforms, during two monitored transport trips. It is important to note that although fecal coliform levels exceeded the guideline limit (dotted line) by the end of these trips, *E. coli* levels remained low. Substantial increases in APC were also observed during transportation (data not shown).

The temperatures of summer oysters at dockside were often greater than 30° C. This load of heat was retained for long periods, even though the oysters were shipped in refrigerated trucks. For example, one trip to Florida required 13 h of travel time, and the temperature of the oysters had dropped from $32-35^{\circ}$ C at dockside, only to about $14-20^{\circ}$ C, by the trips end. These high temperatures were conducive to microbial growth, and may help to explain why oysters often had high aerobic plate counts and high fecal coliform counts. Typical commercial practices for shipment of summer oysters consisted of loading sacked oysters, at ambient temperature, into insulated trailers, also at ambient temperature, and the trucks' refrigeration units were started as the trips began. The refrigeration units on transport trucks were designed to maintain the cool temperature of perishable, refrigerated foods during transport. However, these units are not adequate for

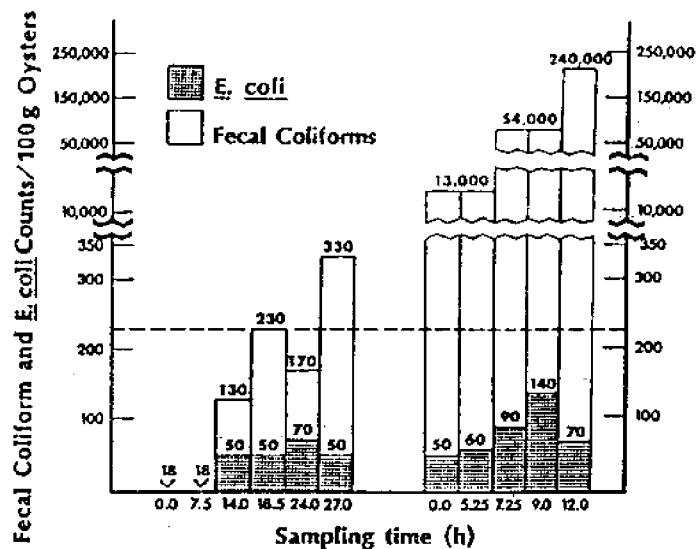


Fig. 1. Effects of transportation on fecal coliform levels.

initial chilling, removing the thermal load from a large mass such as 400 sacks of oysters. Impediments to cooling were introduced by the method of packaging and the way that trucks were loaded. The oyster sacks, themselves, provided a barrier to air flow. They were rather tightly woven and were often soaked with water. Sacks of oysters were stacked onto the bare floor of the truck, starting at the front end. This stacking method produced a thermal mass which was almost a single unit, with impaired circulation of air between the sacks. Some states require that sacks of oysters be stacked on pallets for transport, but this may channel air under the stacks and discourage air circulation even more than stacking on the bare floor. Improved cooling might be accomplished by separating the stacks or even by piling loose oysters into the truck.

Refrigeration of oysters on board the fishing vessel or on board a "mother ship" may help to improve the microbiological quality of summer oysters. Such an arrangement was tried by at least one oyster harvester, but costs and peer pressures prevented his continuing the operation.

Another problem encountered in transportation was the apparent percolation of water down through the stacked sacks of oysters, carrying bacterial contaminants with it. Stacking and nesting of product containers causes microbiological problems and is discouraged in other food industries, so, it is reasonable to be suspicious of this practice in the oyster industry.

The sacks were often found to be heavily contaminated, and moist

conditions may have worsened the situation, by allowing bacteria to multiply. This problem was greatly compounded during truck transport. Moisture from the oysters and the sacks quickly saturated the atmosphere inside the transport truck. Slow cooling caused supersaturation, and water condensed on the walls, floor, and ceiling of the trailer and added to the percolation. The atmosphere inside of trailers sometimes contained water droplets, such as in a cloud or fog.

The fishermen claim that oysters gap open, when left outside in a heavy fog. We were unable to observe this phenomenon or duplicate it in the laboratory. However, the occurrence of gapping in the supersaturated truck atmosphere could have allowed contaminants from the sacks or from the drip to get inside of the oysters.

The oyster sacks, as mentioned, appeared to be important sources of contamination. Oyster sacks were large burlap bags (usually reclaimed coffee sacks) which were used repeatedly. Emptied sacks were usually dried before they were returned to the boats, by being spread or stacked on the ground near the boat dock, or on the shell pile or parking lot at the processing plant. This practice presented opportunities for the sacks to become contaminated. By the time sacks had been used three or four times, they often contained high numbers of *E. coli* or other fecal coliforms. Table 2 lists microbiological data obtained for spot checks of sacks collected on oyster boats, at dockside, or at processing plants. Even "new" sacks contained some fecal coliforms, probably introduced by the coffee which they had previously held. The experimental polypropylene sacks appeared to retain less bacterial load than the conventional burlap sacks.

Table 2. Contamination levels in Oyster Sacks

SACK DESCRIPTION	AEROBIC PLATE COUNT/g	FECAL COLIFORMS/g
"New"	--	0.8
"New"	1.4×10^5	1.t.2
Used once	g.t. 10^6	920
Used once	--	1600
Used once	--	920
Used several times	4.5×10^6	110
Used several times	--	350
Much used	9.6×10^7	g.t.240
Sun dried	--	1.3
Used, used today	--	g.t. 2400
Polypropylene, used today	4.8×10^3	0.2

g.t., l.t.: greater than, less than.

Alternative methods of packaging were tested, including sacks made of less-absorbant polypropylene material and lidded plastic pails. Shipment of oysters in these containers improved the quality somewhat,

except that elevated E. coli counts were seen in the polypropylene-sacked oysters. More trials are needed to determine whether this was merely a chance occurrence. A promising container design, worthy of further study, would be an extruded plastic crate, similar to a milk crate. This would be sanitizable, would be sturdy and have a long life. It would be well vented for air flow and a continuous lid could minimize drip percolation. There would, however, be some drawbacks in initial cost and storage space needs.

Oyster boats are usually docked, where there is road access, to facilitate the transfer of harvests to trucks. This generally implies proximity to human habitation, and often, the waters in docking areas may contain domestic or industrial pollutants. It is important that oyster fishermen recognize and guard against the contamination problems of splashing or shipping polluted water, or deck washing with raw water from these sources. A seasonal variation was observed in the organisms which comprised the fecal coliform population of commercial oysters. Escherichia coli was the principal fecal coliform during the winter and spring months, when water temperatures were cool. However, when temperatures were higher, during the summer and fall months, non E. coli fecal coliforms came to predominate.

In summary, some non E. coli fecal coliforms may multiply in Louisiana oysters. Economic losses have resulted, when high levels of these bacteria caused suspicions of oyster safety. Increases in fecal coliforms and aerobic plate counts were observed during harvesting, handling, and transportation of oysters. Harvesting, handling, and transportation practices often influence the quality and shelf life of other foods. So, it is not surprising that this also occurs in the oyster industry.

Effective means for improving the microbiological quality of oysters and lowering the non E. coli fecal coliform levels might include improvements in containers for shellstock, greater attention to on-vessel handling practices, and more efficient cooling of oysters prior to shipment.

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OYSTERS, FECAL COLIFORMS AND MUG

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INTRODUCTION

Due to the confusion that surrounds interpretation of coliform determinations in foods, a need exists for a more direct and rapid method for enumerating Escherichia coli. The reason for this need is based on the assumption that E. coli is considered a more reliable indicator of fecal pollution than fecal coliforms (4). With the reporting of a rapid fluorogenic procedure by Feng and Hartman (4), it appeared that this need had been satisfied. Early studies with this procedure have all shown its utility with a variety of foods (1,6). However, when first applied to oysters in our laboratory, the results were extremely confusing. The substrate, MUG, had been added to the LST broth as suggested (4) in the MPN procedure for determining coliforms. Following incubation, E. coli positive tubes should fluoresce under long-wave UV light due to the enzymatic breakdown of 4-methylumbelliferone glucuronide (MUG) by a glucuronidase enzyme produced by this organism. However, all of the lower dilution tubes fluoresced and E. coli could not be recovered from many of the tubes. Further investigation showed that oysters and a few other animals also produce the enzyme involved in the assay (9), thereby invalidating its use with these products.

This is a report on our modification of the procedure for determining E. coli in oysters by incorporating the MUG into EC rather than the LST broth. In addition, all organisms growing in positive EC tubes were isolated and identified to species to aid in interpretation of results from the fecal coliform analysis as it relates to the analysis of oysters.

MATERIALS AND METHODS

Oysters (pints and shellstock) were obtained at retail markets in the Gainesville, FL area. Initial 1:2 dilutions were prepared using Butterfield's Phosphate Buffer (8) and blended for 2 min. in a Hamilton Beach blender. The standard 5-tube MPN procedures (7,8) were followed for the total and fecal coliform analyses.

During the preliminary studies, MUG was incorporated into the LST broth at a concentration of 0.1 mg/ml. However, all the lower dilution tubes fluoresced due to a glucuronidase enzyme endogenous to the oysters. Thereafter, 25 oyster samples were tested with 0.1 mg/ml of MUG incorporated into the EC broth used in the fecal coliform analysis. Positive gassing LST tubes were transferred to EC broth, and after 24 and 48 h at 44.5 C, the tubes were observed for fluorescence using a long-wave UV

light. All positive gassing tubes, fluorescent or not, were streaked onto Levine's EMB agar. Isolates were identified by picking onto Veal Infusion agar and Triple Sugar Iron agar slants followed by biochemical tests (2).

RESULTS AND DISCUSSION

Table 1 shows the results of incorporating the MUG into the EC broth during the fecal coliform analysis. Of the 127 positive EC tubes, 103 fluoresced and E. coli was isolated from 102 of the tubes. The one fluorescent tube that was negative for E. coli probably resulted from missing the colonies when picking from the EMB plate. The isolates that were picked tested negative for fluorescence when reinoculated into MUG-EC broth. None of the EC positive tubes that did not fluoresce contained E. coli. In addition, raising the incubation temperature from 35 to 44.5°C resulted in the elimination of many contaminating organisms usually present in positive LST tubes making isolations much easier. Of the 25 samples analyzed, 2 pints and 3 shellstock samples exceeded an MPN of 230 E. coli per 100 g, whereas, 4 pints and 5 shellstock samples exceeded the official regulations of 230 fecal coliforms per 100 g sample.

Table 1: Effect of incorporating MUG into EC broth on the isolation of Escherichia coli from oysters (25 samples)

Total positive EC tubes	127
Total fluorescent tubes	103
Fluorescent +, <u>E. coli</u> +	102
Fluorescent +, <u>E. coli</u> -	1
Fluorescent -, <u>E. coli</u> +	0

The data in Table 2 lists the organisms isolated from the positive fecal coliform tubes and some of their characteristics. It is noteworthy that 6 of the 7 organisms isolated are recognized clinical pathogens and the seventh probably is also (5). This would indicate that the fecal coliform assay does indicate the presence of organisms of public health concern in oysters, although, it does not monitor the presence of a specific pathogen. It may be possible that the broad recovery of many opportunistic pathogens in the fecal coliform analysis results in the exclusion of many samples of oysters that are potentially dangerous to the consumer. This fact must be considered when efforts are made to change existing standards to those based on E. coli. This change in effect would result in the relaxing of standards with a possible increase in oyster-associated gastroenteritis.

Table 2: Some characteristics of organisms recovered from gas positive EC tubes

<u>Organism</u>	<u>Saprophytic Growth</u>	<u>Pathogenic</u>
<u>Citrobacter intermedius</u>	yes	probably
<u>Enterobacter aerogenes</u>	yes	yes
<u>Enterobacter cloacae</u>	yes	yes
<u>Escherichia coli</u>	yes	yes
<u>Klebsiella pneumoniae</u>	yes	yes
<u>Proteus mirabilis</u>	yes	yes
<u>Pseudomonas aeruginosa</u>	yes	yes

However, as shown in a recent report (3), the use of MUG in determining the presence of E. coli in foods may only be of academic interest. This study showed that none of 5 strains of E. coli involved in causing hemorrhagic colitis in humans hydrolyzed MUG. In addition, these strains were also not able to grow at 44.5 C. Both these observations place severe limitations on the usefulness of these procedures for enumerating E. coli in foods, particularly those strains that are overt pathogens.

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LOW DOSE GAMMA IRRADIATION OF VIBRIO CHOLERAE IN OYSTERS
(CRASSOSTREA VIRGINICA)

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INTRODUCTION

Most oysters are distributed as fresh or chilled products (7). Due to the short shelf life of fresh oysters, they can not be marketed great distances from their source. Oysters can be treated with pasteurization doses of irradiation (100 to 1000 krad) to reduce their microbial population and thereby extend their shelf life. Oysters treated with 200 krad and stored in crushed ice are still acceptable after 21 days, but unirradiated oysters stored under the same conditions spoiled (7).

Live oysters take in their own weight in water every two hours, therefore, they may become contaminated with pathogenic microorganisms in their environment. There have been 31 cases of Vibrio cholerae infections reported in the United States since 1973 (4). Although oysters have not been definitely implicated as the source of the organism in any of these cases, contaminated oysters have been responsible for cholera epidemics occurring in Portugal (2) and in Italy (1).

The purpose of this study was to determine the effect of pasteurization levels of irradiation on V. cholerae in oyster meat and the effect of cold storage on the survival of the organism in the oyster meat.

MATERIALS AND METHODS

Preparation of oyster homogenate. Fresh oysters were purchased from local seafood markets. The oysters were drained of excess fluid and placed in a Waring Blendor. The oyster meat homogenate was prepared by blending 3 parts fresh oyster meat after draining of excess fluid, with one part sterile saline. The homogenate was then inoculated to produce a final concentration of 10^7 Vibrio cholerae 01/g (biotype eltor, serovar Inaba, Louisiana Strain #5875). The pH of the homogenate was adjusted to 6.0 if necessary. The sterile oyster meat homogenate was prepared in the same manner, except the oyster meat was sterilized at 121°C for 15 minutes before blending.

Preparation of inoculum. On two consecutive days V. cholerae was transferred to fresh peptone salt agar (PSA) and incubated for 18 to 24 hours at 35°C. The organism was washed from the PSA with 1 ml of peptone water (PW), and 0.1 ml of the suspension was transferred to tubes containing 10 ml of PW. These tubes were incubated at 35°C for 18 to 24 hours. After incubation the V. cholerae suspension was centrifuged at 8000 rpm for 10 minutes in a Sorvall Superspeed RC2-B

centrifuge. The supernatant was discarded and the bacteria were suspended in 10 ml of saline. This washing procedure was repeated twice more, and the bacteria were then suspended in 1 ml of saline. A population of 1×10^9 V. cholerae/ml was produced by placing a sufficient amount of the suspension in a saline solution to produce an absorbance (A_{650}) of approximately 0.46 on a Bausch and Lomb Spectronic 70 spectrophotometer. The inoculum was added to the oyster homogenate to produce a final concentration of 1×10^7 V. cholerae/g. The inoculated samples were placed in 250 ml Nalgene bottles, packed in ice, and transferred to the Nuclear Science Center at Louisiana State University.

Irradiation of the samples was performed by placing the Nalgene bottles containing the samples in a water tight chamber filled with ice and sealed. The chamber was then lowered into the 18 feet deep and 6 feet diameter lead lined pit which was filled with water providing the effective radiation shield. The Colbalt-60 source dose rate was 1650 rad per minute. The samples were exposed to 25, 50 and 100 Krad based on the number of rads emitted per minute as a function of time to attain the desired dosage. The samples were then removed, packed in ice and transferred to the Food Science Department for analysis and examined for the presence of V. cholerae at 0, 7, 14 and 21 days cold storage at -8°C , 0°C and 4°C . Control samples were treated in the same manner, except the irradiation treatments were omitted. The number of V. cholerae surviving was calculated by determining the average number of V. cholerae recovered from triplicate samples subjected to the same irradiation treatment and cold storage.

Recovery methodology for V. cholerae on oyster meat homogenates included recovery from a 6-8 hr alkaline peptone water (APW) enrichment and isolation on thiosulfate-citrate-bile salts-sucrose (TCBS) and gelatin agar. After incubation at 35°C , suspect V. cholerae colonies growing on the TCBS were transferred to and confirmed with Kleiger's iron agar (KIA) and lysine iron agar (LIA), and serologically with Polyvalent and Inaba Vibrio cholerae 01 antiserum.

RESULTS AND DISCUSSION

Effect of irradiation. It has been reported that the refrigerated shelf life of raw oysters can be extended by using pasteurization doses of irradiation to reduce the natural microbial flora of the oysters (7). Oysters treated with 200 krad and stored in crushed ice are still acceptable after 21 days. The total plate counts of the fresh oysters were reduced by 99% (7).

Data illustrated in Figure 1 show that pasteurization levels of irradiation are also useful for reducing the number of V. cholerae in oysters contaminated with the organism. In the unsterile homogenates the number of V. cholerae present was reduced from 1.23×10^6 /g to 1.5×10^2 /g with 25 krad of irradiation. No V. cholerae were recovered from the unsterile samples treated with 50 or 100 krad.

In the sterile homogenate, the V. cholerae population was reduced from 6.53×10^6 /g to 1.07×10^1 /g with 25 krad of irradiation (Figure 1). No V. cholerae were recovered from the sterile samples treated with 50 or 100 krad.

Effect of time. The most cases the V. cholerae population of the homogenate decreased during the 21 day cold storage period. In the unsterile homogenate stored at 4°C , the initial decrease in the number of V. cholerae was followed by an increase in the number of V. cholerae recovered (Figure 2). The original population of 7.23×10^6 decreased to 9.3×10^3 /g on day seven, but increased to 1.3×10^6 /g on day 14. No V. cholerae were recovered from the homogenate on day 21, however.

The unsterile homogenates treated with 25 krad and stored at 4°C exhibited the same pattern as the unirradiated samples. There were 1.57×10^2 /g recovered from the homogenates on day 0, but no cholera organisms were recovered from the unsterile homogenates stored for 21 days at 4°C .

Vibrio cholerae was able to survive for 21 days in the unirradiated sterile homogenates and in the homogenates treated with 25 krad and stored at 4°C (Figure 3). There were 6.53×10^6 V. cholerae/g recovered from the unirradiated sterile homogenate on day 0, and 1.11×10^6 /g were recovered on day 21. A survival pattern very similar to this is seen in sterile oyster homogenates inoculated with 10^6 V. cholerae/g and stored at 7°C for 21 days (9). In the sterile homogenates treated with 25 krad, 1.07×10^1 V. cholerae/g were recovered on day 0, and 1.33×10^0 V. cholerae were recovered on day 21.

Vibrio cholerae was not able to survive for 21 days in the unsterile homogenates which were stored at 0°C (Figure 4). In the unsterile homogenates which were not irradiated 7.23×10^6 V. cholerae/g were recovered on day 0, but no V. cholerae were isolated from the homogenates on day 21. The V. cholerae population on the unsterile homogenates treated with 25 krad also declined during storage at 0°C . As in the unsterile homogenates stored at 4°C , there was a decrease in the V. cholerae population between day 0 and day 7, and an increase in the population between day 7 and day 14. Apparently the changing environmental conditions in spoiling oysters stored at 4°C or 0°C become more favorable for the survival of V. cholerae between days 7 and 14. These conditions may be related to a change in the dominant microorganisms in the oyster's microflora during spoilage as discussed below.

In the unirradiated sterile homogenates stored at 0°C , V. cholerae was able to survive for 21 days (Figure 5). The 6.53×10^6 V. cholerae/g recovered on day 0 decreased to 9.3×10^5 V. cholerae/g on day 21.

In the sterile homogenate treated with 25 krad and stored at 0°C , the V. cholerae population decreased from 1.07×10^1 /g on day 0 to 1.33×10^0 /g on day 14 or day 21.

Results were similar for the sterile and unsterile homogenates stored at -8°C (Figures 6 and 7). There was a progressive decrease in

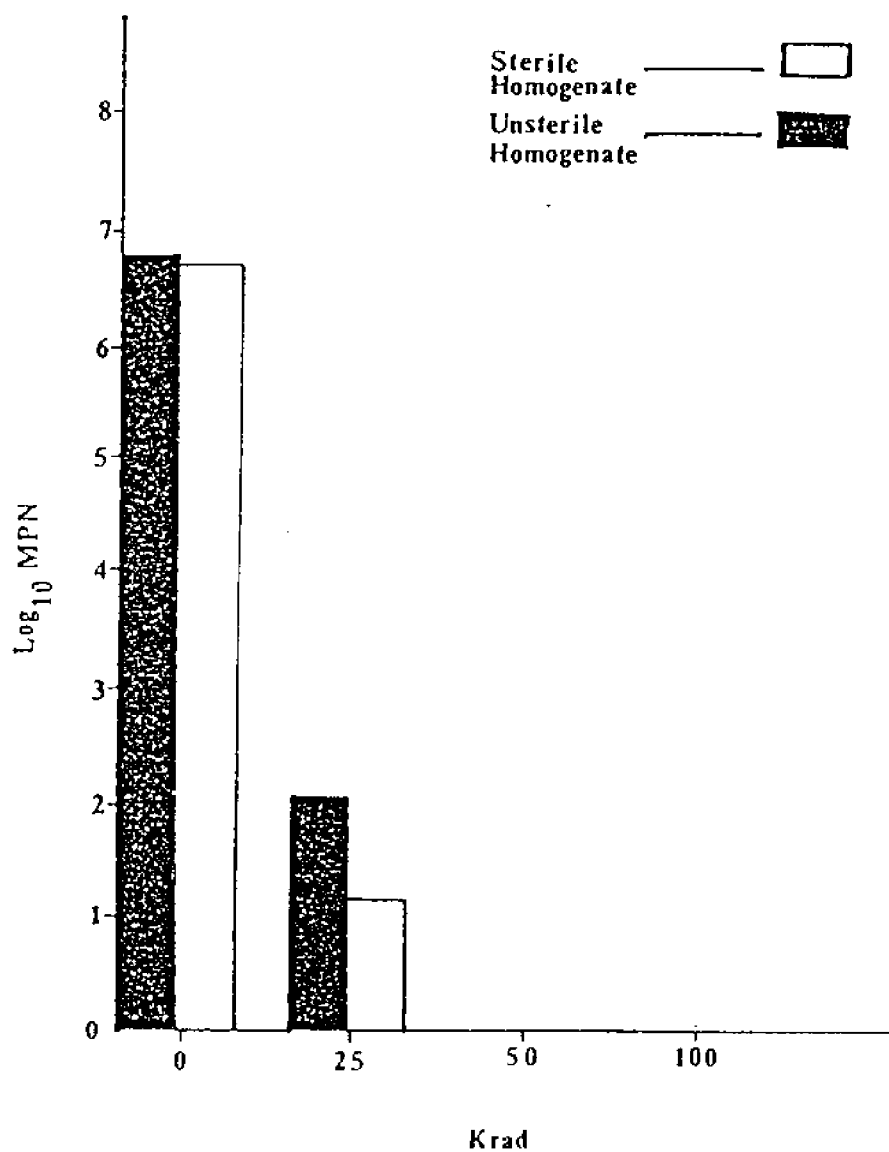


Figure 1. Effect of low dose gamma radiation on *Vibrio cholerae* #5875 in oyster homogenates. MPN values are averages of 3 replications.

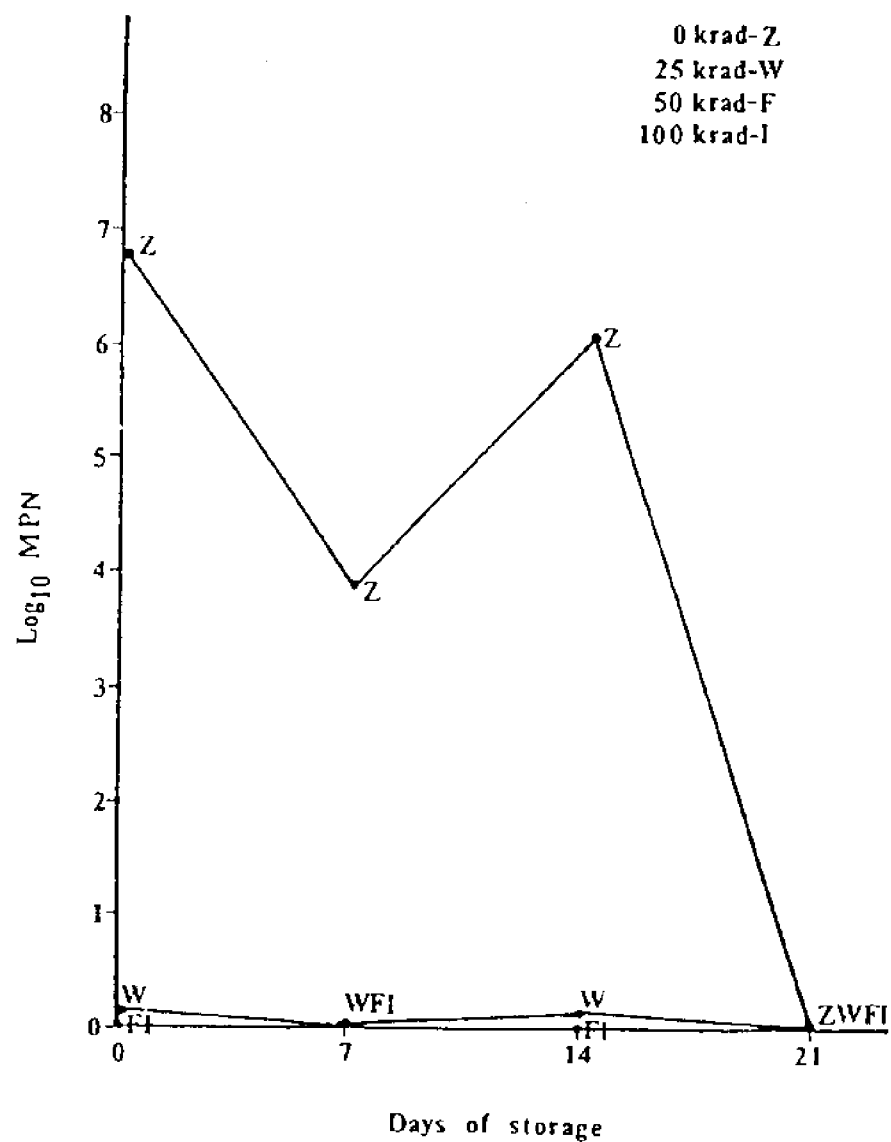


Figure 2. Survival of *Vibrio cholerae* #5875 in unirradiated and irradiated unsterile oyster homogenates stored at 4°C. MPN values are averages of 3 replications.

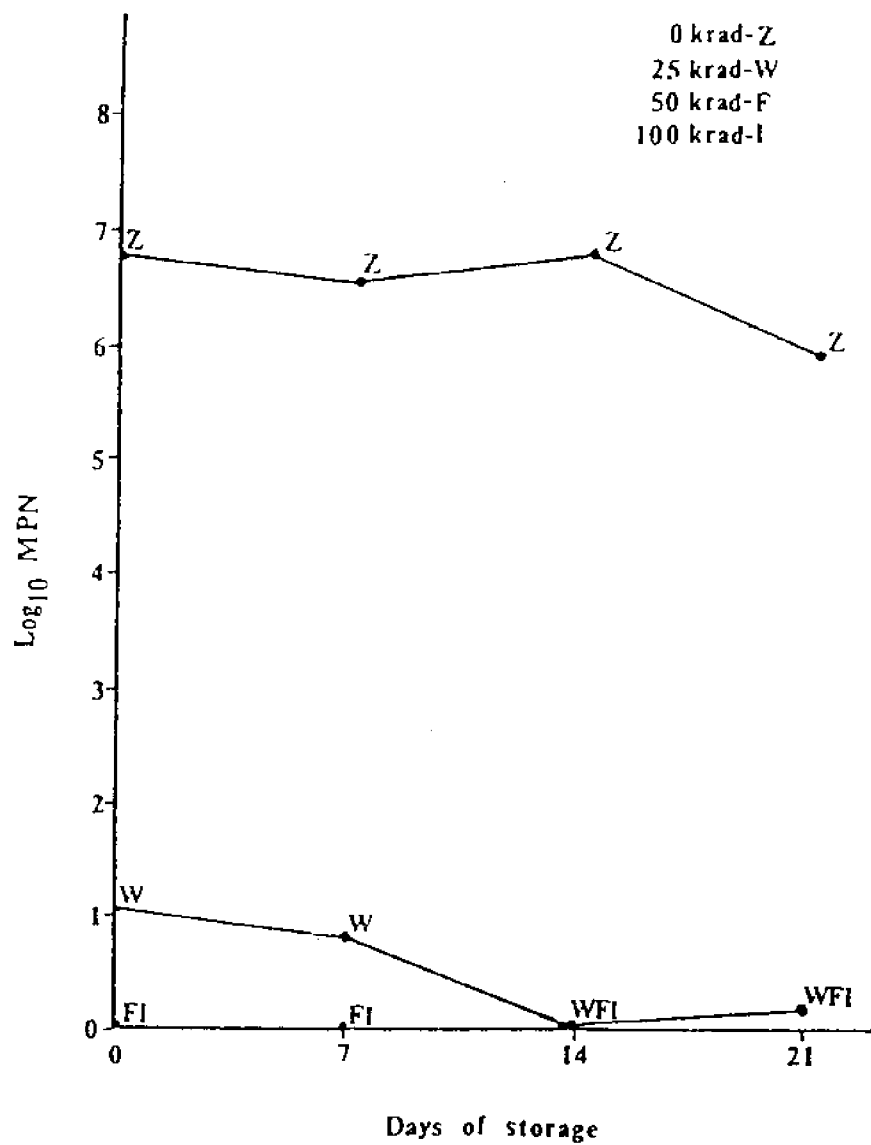


Figure 3. Survival of *Vibrio cholerae* #5875 in unirradiated and irradiated sterile oyster homogenates stored at 4°C. MPN values are averages of 3 replications.

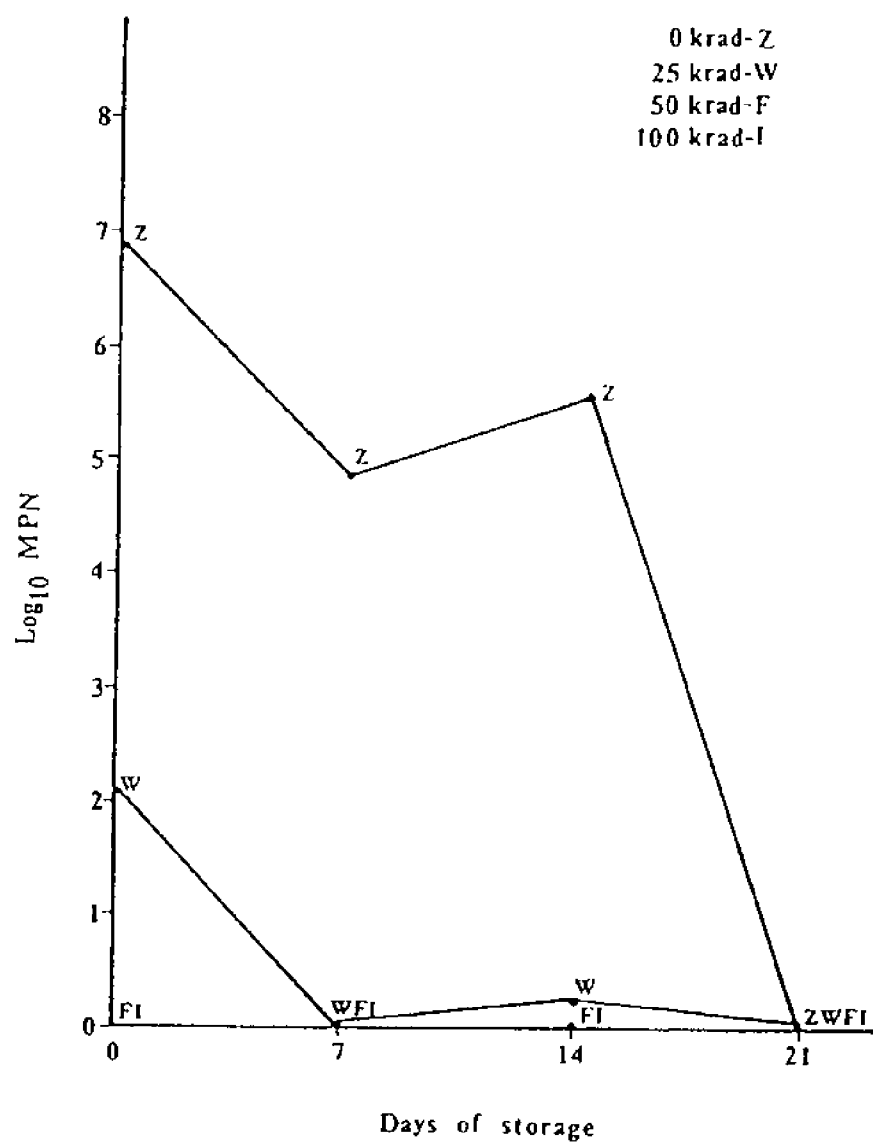


Figure 4. Survival of *Vibrio cholerae* #5875 in unirradiated and irradiated unsterile oyster homogenates stored at 0°C. MPN values are averages of 3 replications.

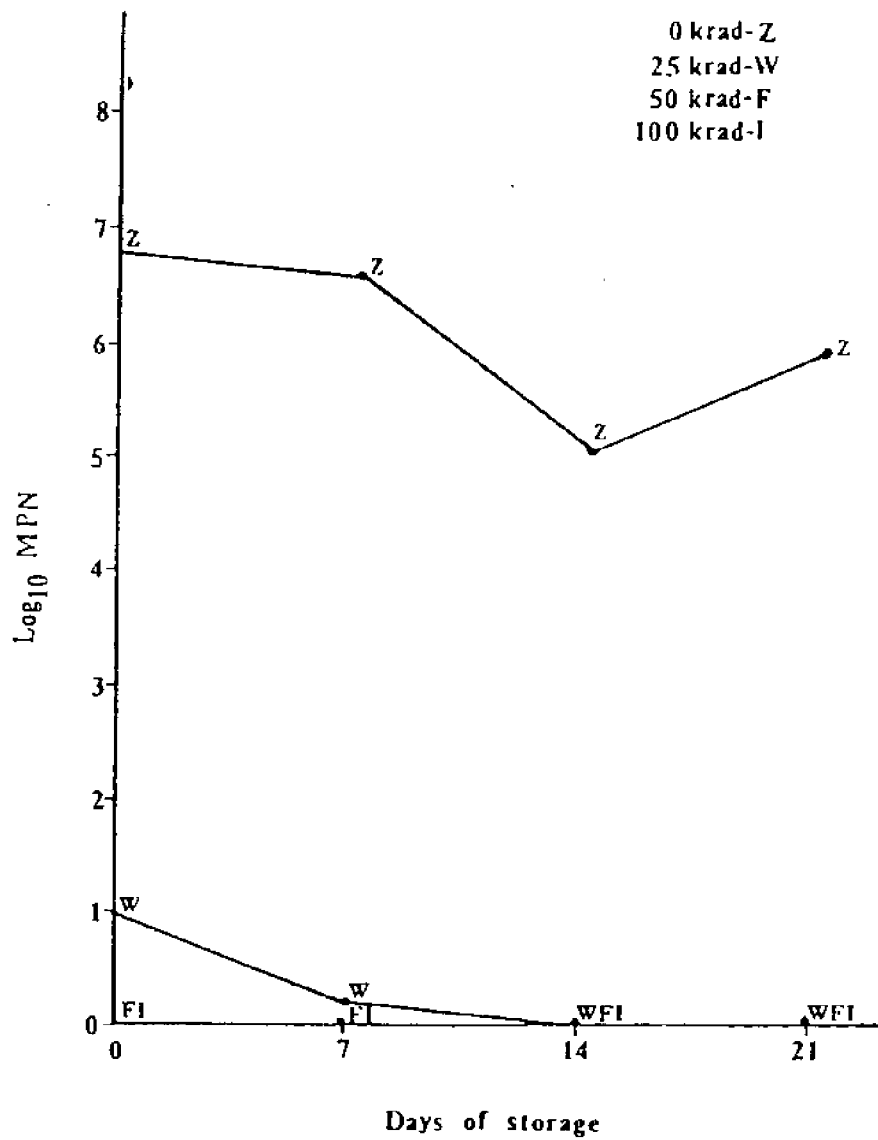


Figure 5. Survival of *Vibrio cholerae* #5875 in unirradiated and irradiated sterile oyster homogenates stored at 0°C. MPN values are averages of 3 replications.

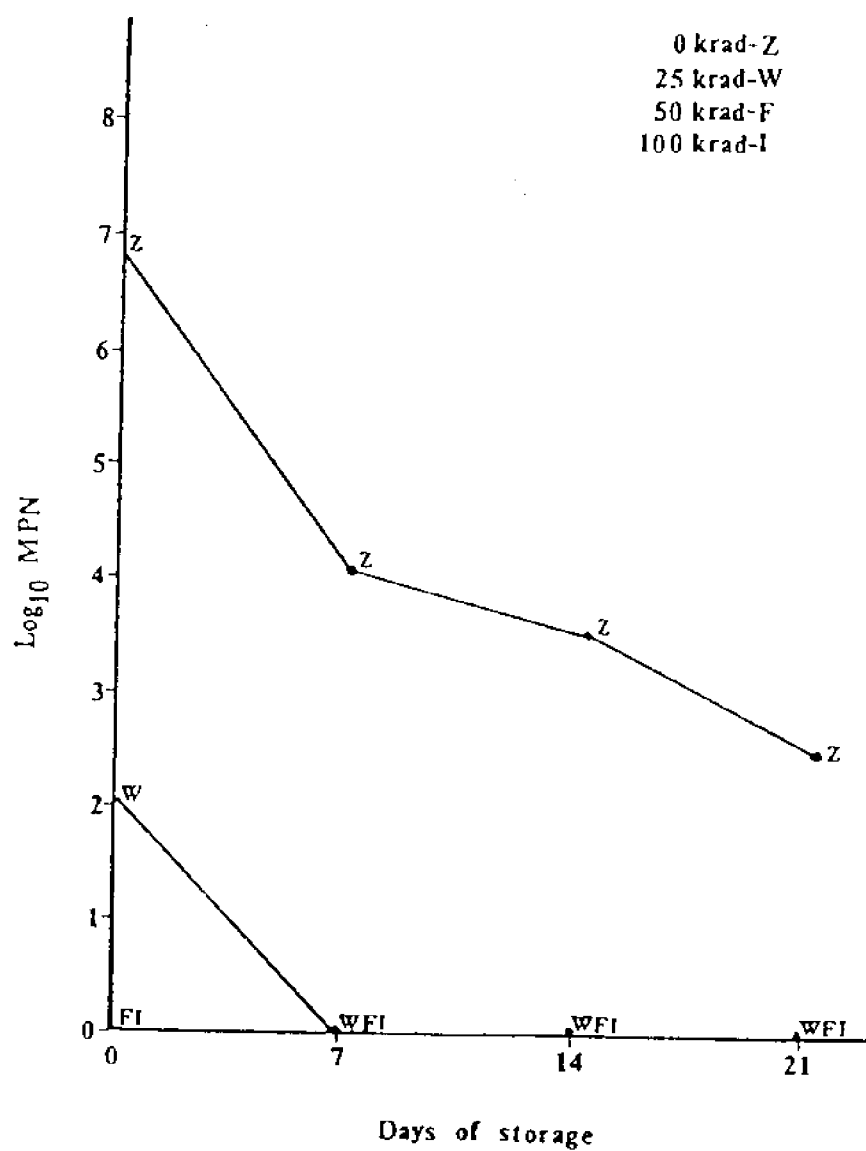


Figure 6. Survival of *Vibrio cholerae* #5875 in unirradiated and irradiated unsterile oyster homogenated stored at -80°C. MPN values are averages of 3 replications.

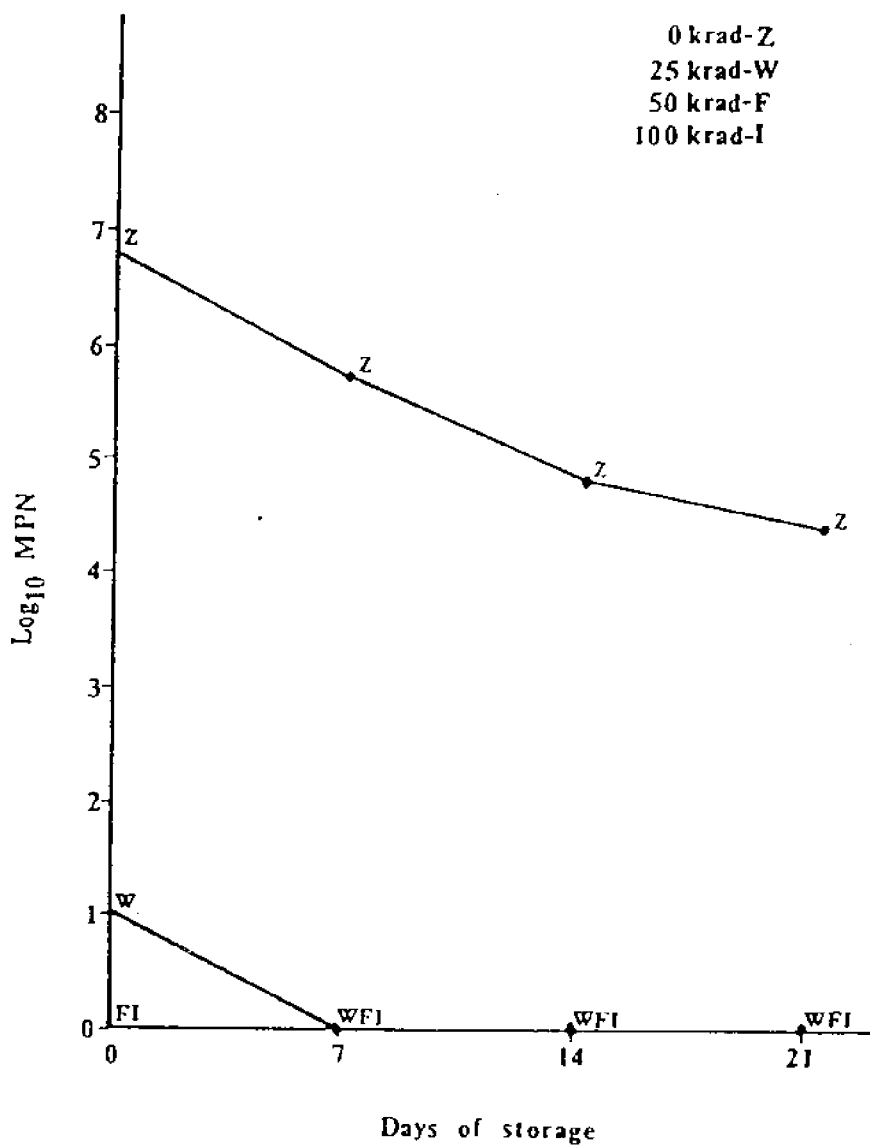


Figure 7. Survival of *Vibrio cholerae* #5875 in unirradiated and irradiated sterile oyster homogenized stored at -80C. MPN values are averages of 3 replications.

the V. cholerae population of each homogenate. In the unsterile samples, the number of V. cholerae recovered decreased from 7.23×10^6 /g on day 0 to only 1.23×10^2 /g on day 21. In the sterile homogenate, the population decreased from 6.53×10^6 /g on day 0 to 2.9×10^4 /g on day 21.

In both the sterile and unsterile homogenates treated with 25 krad and stored at -8°C , no V. cholerae were recovered on day 7, 14, or 21.

Effect of temperature. In most cases, there were relatively small differences in the number of V. cholerae recovered from the homogenates which were treated in the same manner, but stored at different temperatures. In the sterile homogenates the values usually differed by less than 2 log cycles. More V. cholerae were recovered from the sterile homogenates stored at 4°C than at any other temperatures. There were also more V. cholerae recovered from the sterile homogenates stored at 0°C than from those stored at -8°C . This indicates that as the temperature was decreased from 4°C to -8°C there was a decrease in the number of V. cholerae surviving the cold storage. It has been reported that no V. cholerae could be isolated from sterile oyster homogenates inoculated with 10^6 /g of the organism and stored at -20°C for 21 days (9).

Up to day 14 the results obtained in the unsterile homogenate were similar to those seen in the sterile homogenates. After this time more V. cholerae were isolated from the unsterile homogenates stored at -8°C than from the unsterile homogenates stored at 4°C or in ice. Possible reasons for this are discussed below.

Survival in sterile and unsterile homogenates. After seven days of storage, more V. cholerae were usually recovered from the sterile homogenates than from the unsterile homogenates. No V. cholerae could be recovered from any of the unsterile homogenates stored at 4° or 0°C for 21 days.

In the sterilized homogenates, the oyster's natural microflora had been destroyed and the enzymes which were present had been denatured. Members of the genera Lactobacillus and Pseudomonas dominate the microflora of fresh oysters and are primarily responsible for the spoilage of the product (11). Even though the number of microorganisms present is greatly reduced by 100 krad, lactobacilli persist as the dominant microorganism. There are also glycolytic enzymes systems present which can produce acid from the oyster's glycogen (3). Most enzymes are resistant to even sterilization doses of irradiation.

The pH of unirradiated oysters and oysters treated with 200 krad decreases from 6.4 to 5.9 after 21 days of storage in crushed ice (7). Even in oysters treated with 630 krad and stored at 5°C for 14 days, the pH decreases from approximately 6.0 to 5.78 (3).

The lower pH produced by the microbial and enzymatic activity in the unsterile homogenates stored at 4° and 0°C was probably responsible for the decline of the V. cholerae population after day 14. The optimum pH range for the growth V. cholerae is between 7.6 and 8.6 (10), and the viability of the organism is reported to be less in an environment with

a pH between 5.5 and 6.2 than in an environment with a pH greater than 6.2 (8).

In the unsterile homogenates stored at -8°C however, the survival of V. cholerae was only slightly less than in the sterile homogenates. The colder temperatures (-8°C) may have retarded the growth of the natural flora and the enzymatic activity in the oysters and allowed the V. cholerae to survive for a longer period of time

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OYSTER FREE LIQUID CONTENT AND RELATED PHYSICAL AND CHEMICAL CHARACTERISTICS

by

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It is generally accepted that oysters lose fluids when separated from their shells and absorb fluid when placed in fresh water after shucking (10). Most bleeding loss occurs within minutes of shucking (5), while water absorption takes place more slowly and in direct relation to the length of time oysters are in contact with fresh water (9). The Federal standard (3) recognizes both factors and attempts to strike a balance between fluid loss and absorption by limiting water contact time. The Federal standard also includes draining criteria to exclude wash water from finished packs of oysters, and specifies fluid content limits when oysters are packed. These criteria are of only limited regulatory value, however, in that compliance cannot be verified after processing. Resultingly, some states have chosen to adopt additional standards that can be applied at any time shucked oysters are in trade channels. The State of Florida has since 1969 restricted the free liquid content of packed oysters to a maximum of 15% fluid by volume (6) until sale to the ultimate consumer.

Existing free liquid standards have been subject to periodic debate since adoption by federal and state authorities. General agreement exists that some form of regulation is necessary, but opinion varies as to what standard best protects both consumer and industry interests. Scientific literature includes numerous reports on the subject. Some report surveys measuring the fluid content of commercially packed oysters over time (20) or at time of pack (18) under a variety of conditions, while other studies were conducted with oysters packed under controlled circumstances (13, 14). Basic research has also been conducted (5, 9-12, 15, 19). The primary objectives of this study were to review and evaluate several factors which may influence free liquid content, and to re-evaluate Florida's 15% standard in light of knowledge gained.

METHODS AND PROCEDURES

Sampling plan and laboratory procedures were determined prior to onset of the study with two oyster sources, designated "CFR" and "commercial", defined. "CFR oysters" were defined as oysters known (by observation) to comply with Code of Federal Regulations water contact and draining criteria when processed and packed, while "commercial oysters" would be any shucked oysters packed or repacked in retail containers at a recognized Florida processor (2) for entry into trade channels. Commercial samples were further designated "paired" or "independent" depending on their sampling source.

"Paired" commercial samples were drawn from the same production lots from which CFR samples were obtained, while "independent" commercial samples were obtained from other lots.

Laboratory procedures included measurement of several physical and chemical attributes of packed oysters as well as free liquid content. Sample pH was determined using a standard meter equipped with a glass/calomel combination electrode, oyster and free liquid salinity (NaCl) were measured following AOAC official method (16), and the refractive index of sample free liquid was determined using a refractometer with readings corrected to 20°C. The number of oysters in each sample unit and percentage of oysters damaged during shucking were also recorded, and each sample was subjected to periodic organoleptic evaluation. The free liquid content of sample units was determined using a laboratory sieve and graduate cylinder. Drain time on the sieve was two minutes with fluid content recorded in milliliters and as a percentage of retail container volume. The study also included extensive microbiological analyses which will be reviewed in a separate report. All samples were transported to the laboratory in iced styrofoam chests, and were held under crushed ice in refrigerated storage until analyzed. CFR samples were analyzed on day of pack and daily thereafter for 14 days to establish profile data. Commercial samples were analyzed on day of pack and days 7 and 14 after packing. Following completion of the study, data were reviewed for attribute change over time and association with change in free liquid content. Differences between or within classes of oysters were subjected to statistical analysis for significance (1, 17).

SAMPLING PLAN

CFR and paired commercial samples were collected bimonthly from May, 1983 to January, 1984. Shucking, processing and packing procedures were observed at each plant visited, and oysters meeting Code of Federal Regulation criteria were identified for sampling. Paired commercial samples were collected from "straight run" production for the day. CFR samples consisted of 60 retail units (subsamples) and commercial samples 15 units. Three units from each sample were opened at the plant to establish day of pack fluid content, with the remainder identified and transported under ice to the Florida Department of Agriculture and Consumer Services Food Laboratory in Tallahassee. Independent commercial samples were collected throughout the May, 1983 - January, 1984 period, with samples consisting of 15 retail units collected at each plant visited. Three units from these samples were also opened at the plant to establish fluid content on day of pack. In total, 28 commercial production lots were sampled, with CFR samples obtained from five of the lots.

FREE LIQUID OBSERVATIONS

The free liquid content of CFR samples increased from a mean value of

4.3% of container volume on day of pack, to 7.6% on day 14 (Figure 1). Change during this interval was inconsistent. Mean fluid volume steadily increased for eight days post-packing, and then fluctuated between increase and decrease after day eight with a peak volume of 9.3% on day nine. Paired commercial samples from these same lots differed from CFR samples in several respects. The commercial free liquid mean was considerably higher and range broader at all three comparable measurement points (Table 1), and fluid patterns differed. The commercial mean decreased between day of pack and day seven, reflecting early fluid absorption by oysters, in contrast to early oyster bleeding and free liquid gain in CFR samples.

TABLE 1

CFR and Paired Commercial Sample Free Liquid Volumes on Day of Pack, Day 7, and Day 14. Means and Ranges.

		CFR Samples	Paired Commercial Samples
Day of Pack	$\bar{x}$	4.3%	16.5%
	R	1.4% - 7.7%	3.0% - 30.1%
Day 7	$\bar{x}$	6.4%	12.4%
	R	1.8% - 10.0%	2.0% - 24.8%
Day 14	$\bar{x}$	7.6%	16.5%
	R	2.1% - 10.1%	3.9% - 27.3%

The "saddle" pattern created by the three commercial means over time with an elevated beginning point and depressed mid-point is indicative of incomplete water draining when the oysters were packed. Miles (13) made a similar observation when testing commercially packed oysters 1976, and surmised that added water is initially absorbed by oysters due to osmotic pressure. Kramer (9, 10) and Freedman (8) noted a corollary effect. As water is absorbed, soluble constituents of the oyster are lost. They further observed that water absorption generally results in increased oyster size, and that concurrent loss of flavor and nutritive ingredients due to leaching are contrary to consumer interests. Inclusion of water in finished packs of oysters would be in violation of Florida Statutes (7) and the Federal Food, Drug, and Cosmetic Act (4). Both laws deem a food to be adulterated if any substance has been added to increase bulk or weight, or if any constituent of a food has been in whole or part abstracted.

In reviewing the five sets of paired data individually (Table 2), varying degrees of difference between CFR and corresponding commercial samples are evident. Pairs #2, #3 and #4 differ considerably in free

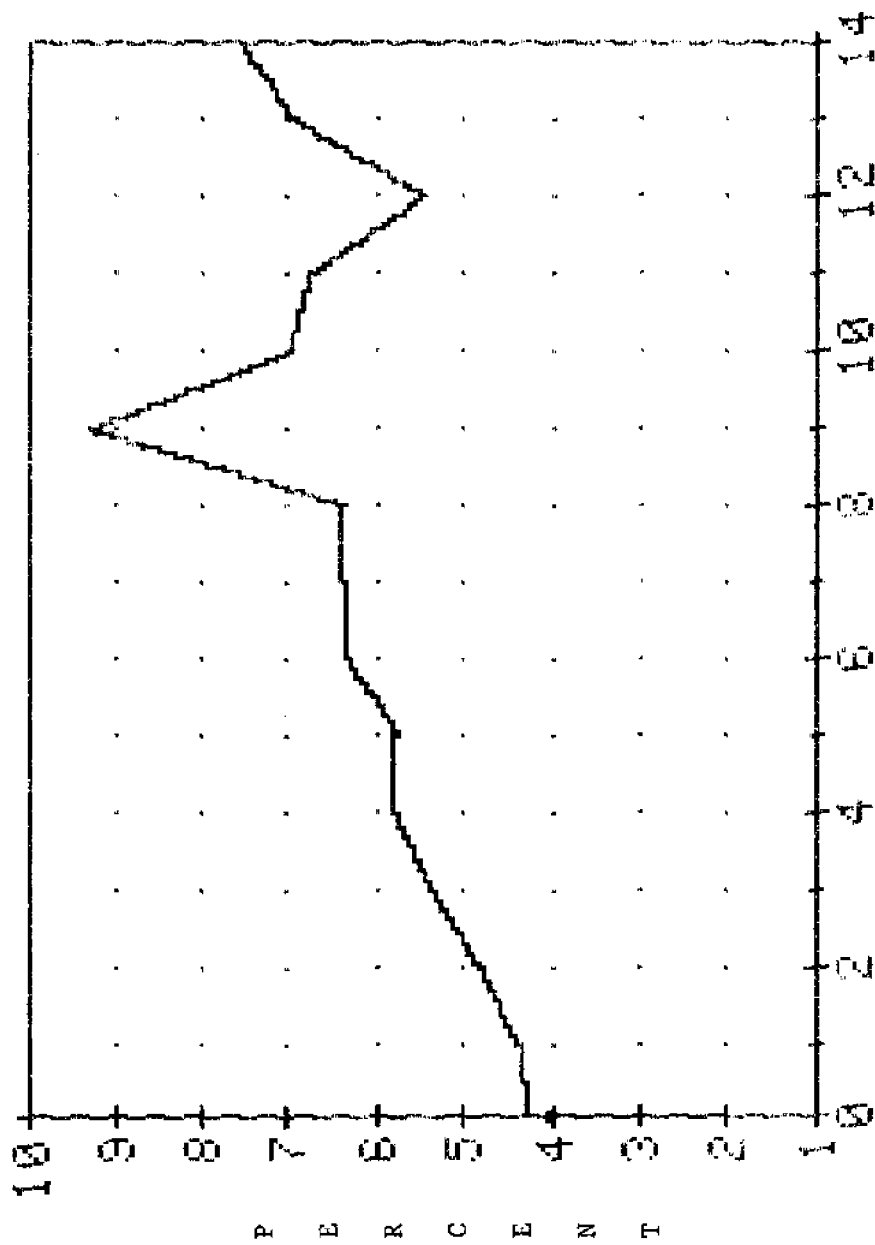


FIGURE 1: Free liquid content. CFR Samples

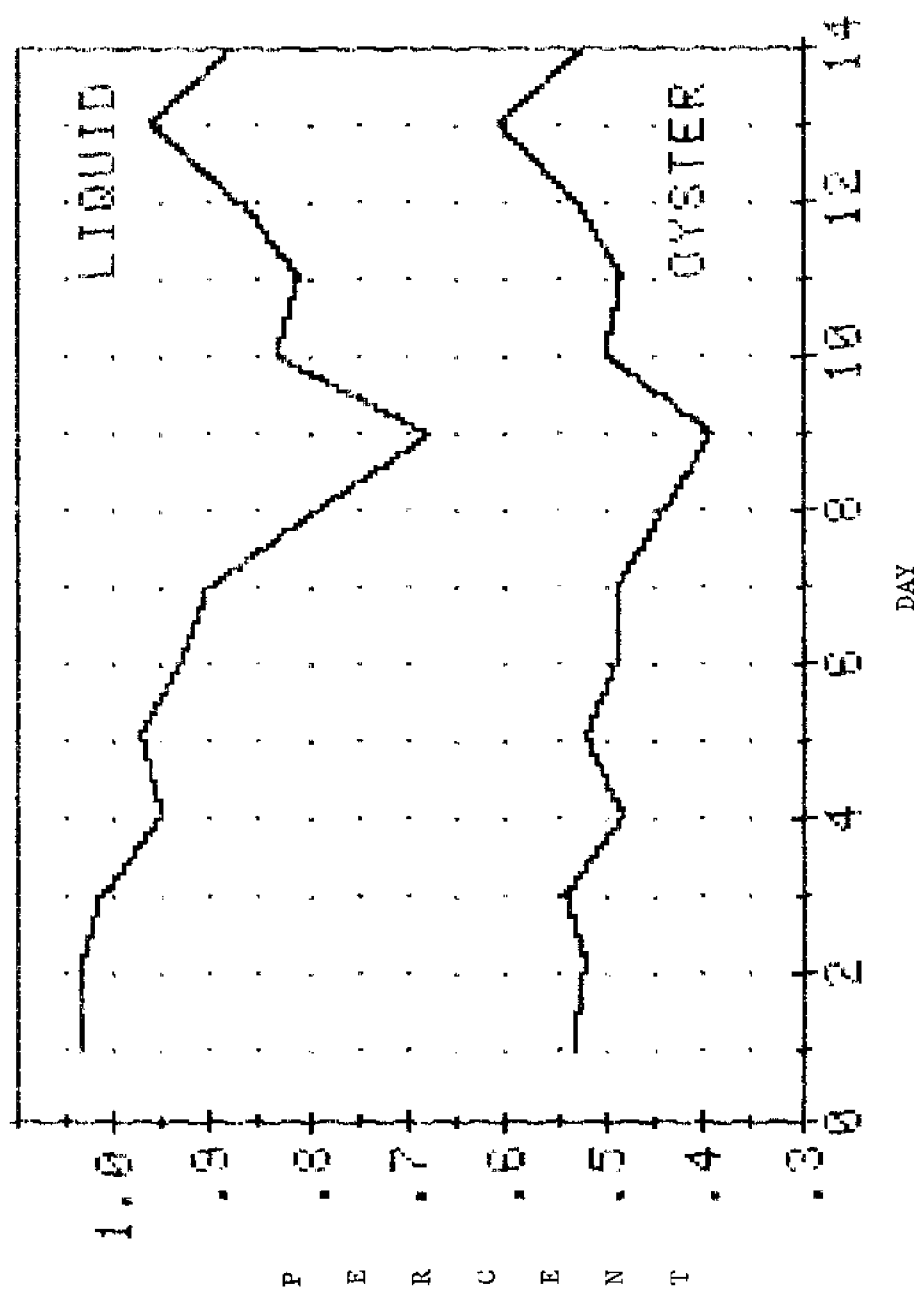


FIGURE 2: Salt (NaCl) content. CFR Samples

liquid volume at all three measurement points, Pair #1 exhibits wide difference in fluid content on day of pack only, and Pair #5 data reflect virtually no difference at any of the three points. As the single variable between the paired samples is "known" or "unknown" compliance with Code of Federal Regulations processing criteria, the data overall reflect varying degrees of compliance. Pairs #1 and #5 were obtained at the same plant ten months apart, while #2, #3 and #4 were obtained at other plants.

TABLE 2

Paired Sample Free Liquid Volumes on Day of Pack, Day 7, and Day 14.

		Day of Pack	Day 7	Day 14
Pair #1	CFR	5.6%	6.9%	9.0%
	Commercial	11.8%	5.4%	10.8%
Pair #2	CFR	7.7%	7.5%	7.9%
	Commercial	16.7%	13.6%	15.9%
Pair #3	CFR	1.4%	6.0%	8.9%
	Commercial	30.1%	24.8%	27.3%
Pair #4	CFR	4.4%	10.0%	10.1%
	Commercial	21.1%	16.4%	24.6%
Pair #5	CFR	2.6%	1.8%	2.1%
	Commercial	3.0%	2.0%	3.9%

Data from independently sampled commercial lots paralleled paired observations (Figure 3). The independent mean was slightly higher than the paired commercial mean at each of the three measurement points, but differences between the commercial means are statistically insignificant. Differences between the commercial and CFR means, however, are statistically significant at all three points.

A majority of commercial samples in the study (21 of 28) exhibited early absorption of fluid by oysters and a resulting free liquid "saddle" pattern as described above. This pattern is strongly associated with elevated free liquid content when oysters are packed, which is demonstrated by separating the samples into "linear" and "saddle" groupings (Figure 4).

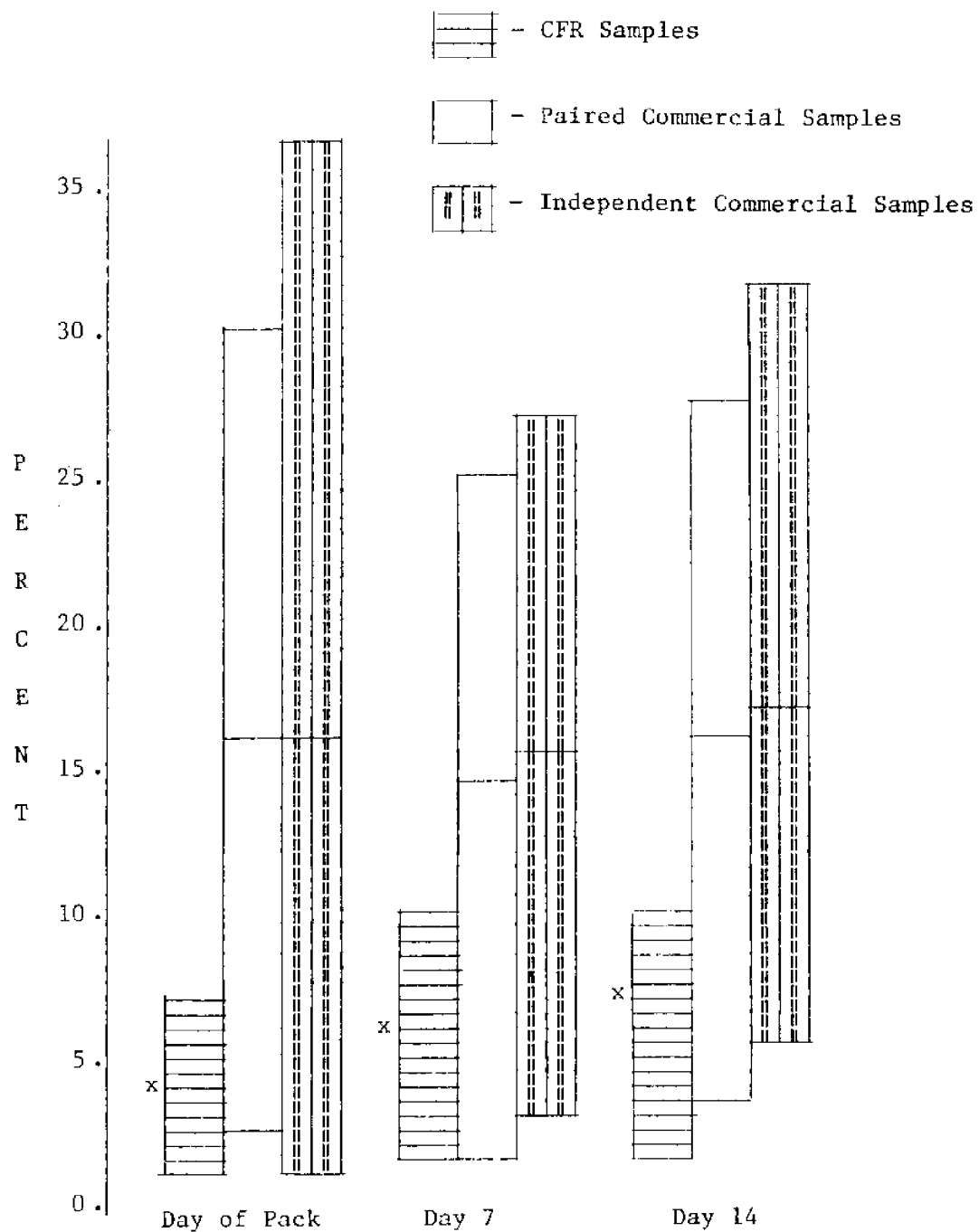


FIGURE 3: Free Liquid Content, CFR and Commercial Sample Means and Ranges on Day of Pack, Day 7, and Day 14.

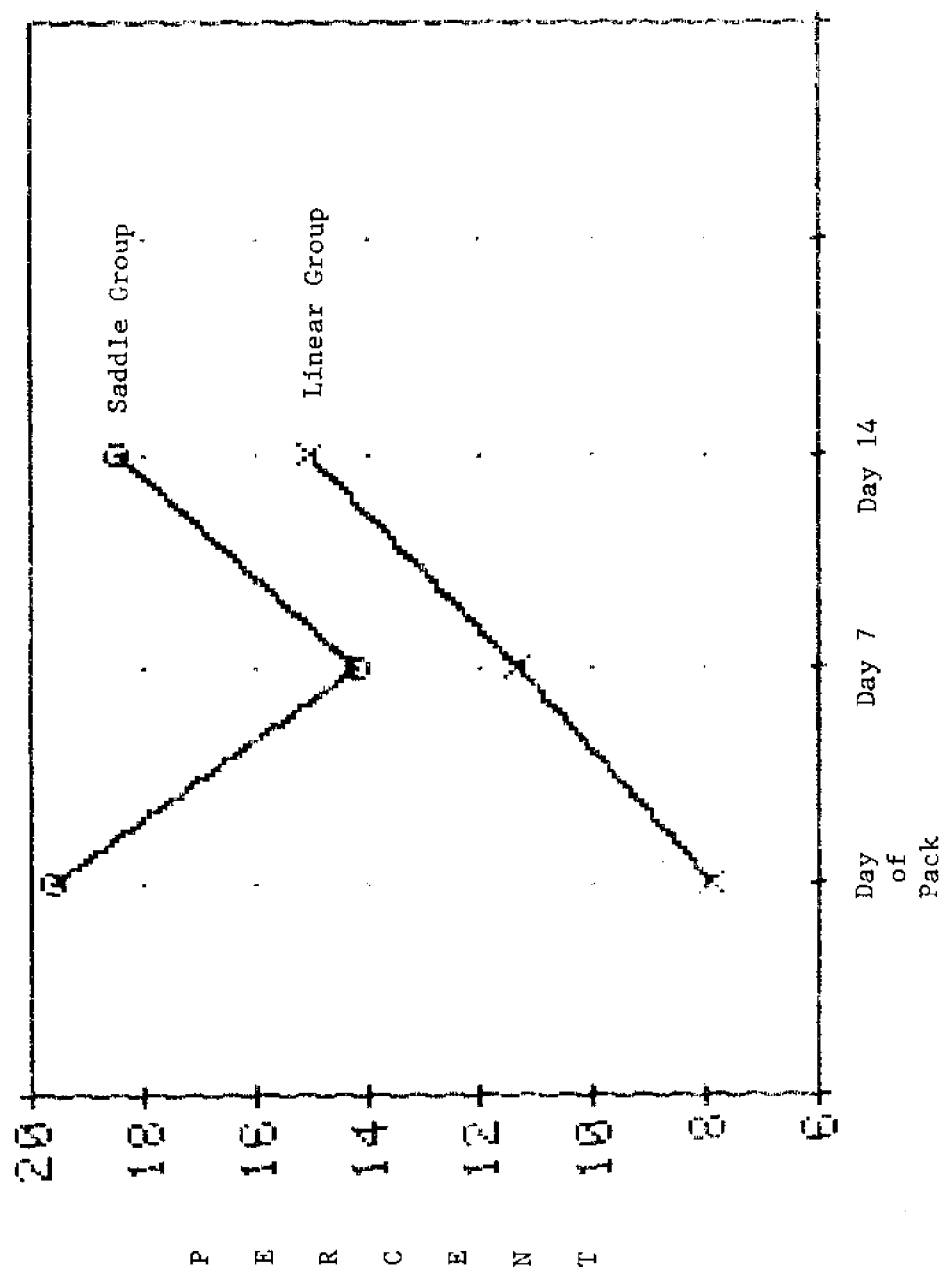


FIGURE 4: Free Liquid Content on Day of Pack, Day 7, and Day 14. Commercial Samples.

Samples in the "linear" group (those samples reflecting linear increase in free liquid content, day of pack to day 7 to day 14) averaged 7.9% free liquid when packed, while samples in the "saddle" group averaged 19.6% free liquid on day of pack.

Half of the commercial lots (14 of 28) contained a greater volume of free liquid when packed than fourteen days after packing, indicative of the oysters ability to absorb and hold water when production lots are inadequately drained. 13 of these 14 lots also exhibited a free liquid "saddle" pattern (Table 3), further demonstrating the association between elevated day of pack free liquid content and non-linear fluid pattern.

TABLE 3

Classification of Commercial Samples by Volume of Free Liquid on Day of Pack and Free Liquid Pattern. 2X2 Contingency Table.

	Free Liquid Pattern	
	"Saddle"	"Linear"
Samples With Greater Free Liquid Volume on Day of Pack Than on Day 14	13	1
Samples With Lesser Free Liquid Volume on Day of Pack Than on Day 14	8	6
Chi-Square = 4.76, 1df P < .05		

Half of the commercial lots sampled also exceeded Florida's 15% free liquid limit on day of pack, and 16 of 28 exceeded tolerance on day 14. Not unexpectedly, lots exceeding 15% free liquid content when packed also tended to exceed tolerance 14 days later (Table 4).

SALINITY

The sodium chloride content of free liquid and oyster meats in each subsample were determined in conjunction with other laboratory procedures. Findings in general reflected published data. Shucked oysters will vary in initial salt content depending on the salinity of the waters from which they are harvested and other factors (19), an inverse relationship between salt content and fluid volume exists

TABLE 4

Classification of Commercial Samples by Compliance With Florida's Maximum Limit of 15% Free Liquid Volume on Day of Pack and Day 14. 2X2 Contingency Table.

Day of Pack Free Liquid Volume	Day 14 Free Liquid Volume	
	Greater than 15%	Less Than 15%
Greater Than 15%	12	2
Less Than 15%	4	10
Chi Square = 9.33, 1df P < .005		

(11), and oyster meats are less saline than surrounding free liquid (10). The inverse relationship between salt and fluid volume is apparent when reviewing CFR sample data (Figures 1 and 2). Day to day change in salinity mirrored change in free liquid content. Each daily increase in fluid volume was accompanied by a corresponding and proportional decrease in salinity, and vice versa. As two salt concentrations are involved, this relationship could superficially be attributed to simple osmosis, but osmosis alone does not account for the observation that liquid and oyster salinities simultaneously shift in the same direction rather than in opposite directions toward a common point. Other processes beyond the scope of this study are obviously involved. The ratio of oyster salt content to free liquid salt content changed with time (Figure 5), perhaps indicating a diminishing ability by oysters to maintain salt equilibrium with their environment after shucking.

Failure to adequately drain oysters prior to packing also affects sodium chloride content via dilution. The effect of water dilution is evident when paired sample data are reviewed (Table 5). Pairs with a marked difference in sodium chloride content also exhibit marked difference in free liquid content on day of pack (Table 2).

Sodium chloride content is not in itself an indicator of water dilution as shell stock salinity can vary. Contingency table analysis of the 28 commercial samples in the study, however, does reveal a strong relationship between "low" salinity and "high" free liquid volume (Table 6).

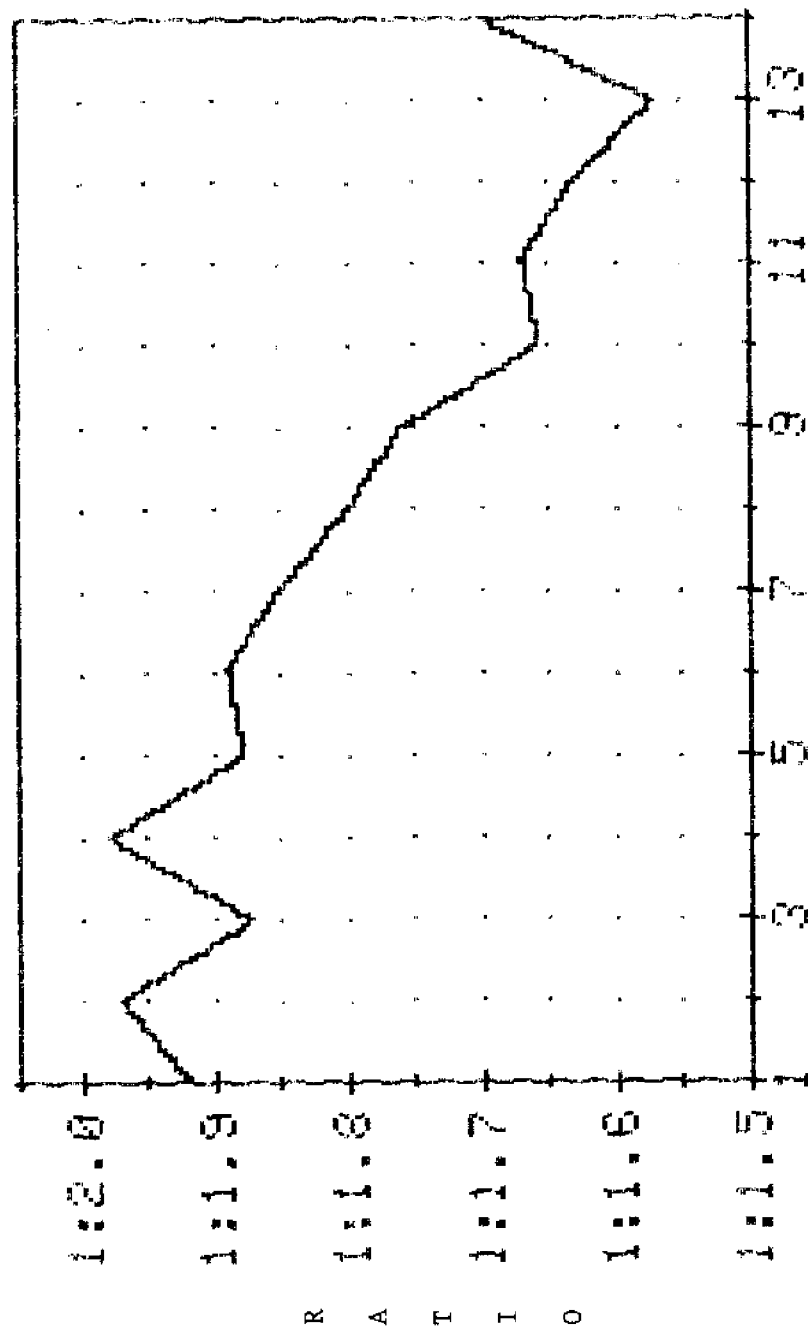


FIGURE 5: Ratio of Oyster Meat NaCl Content to Free Liquid NaCl Content.
CFR Samples

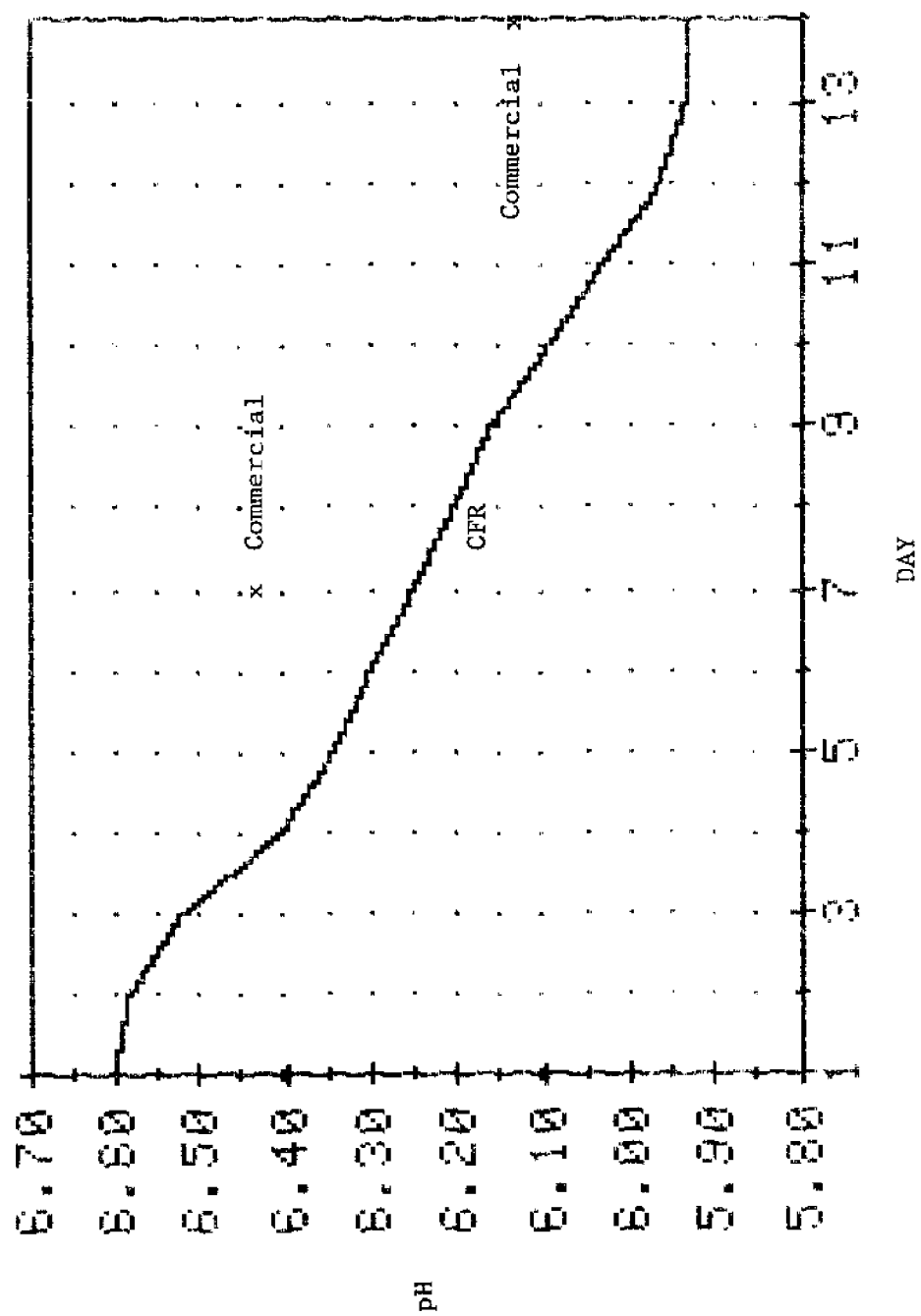


FIGURE 6: pH, CFR and Paired Commercial Samples

TABLE 5

Free Liquid Salt (NaCl) Content. Paired Samples on Day of Pack, Day 7, and Day 14.

	Day of Pack		Day 7		Day 14	
	Oyster	Liquid	Oyster	Liquid	Oyster	Liquid
Pair #1 CFR	.55	.96	.53	.90	.47	.77
Commercial	--	--	.32	.47	.27	.40
Pair #2 CFR	.37	.69	.31	.65	.38	.59
Commercial	--	--	.09	.16	*	.15
Pair #3 CFR	.34	.63	.25	.46	.33	.53
Commercial	--	--	.05	.08	.06	.09
Pair #4 CFR	.85	1.59	.87	1.57	.68	1.29
Commercial	--	--	.37	.65	.17	.23
Pair #5 CFR	.57	1.26	.49	.93	.72	1.20
Commercial	--	--	.48	.90	.55	.97

*No Data

pH

The pH of CFR samples followed a predictable course, slowly declining from a mean of 6.6 on day 1 after packing to a mean of 5.9 on day 14 (Figure 6). Increasing acidity with time is related to advancing oyster decomposition, initially due to enzymic activity and the action of soil and water bacteria, and later due to acid-tolerant microorganisms (8, 11). Paired commercial samples proved less acidic than their CFR counterparts (Table 7). This observation may be due to the practice of adding household laundry bleach to oyster wash water which was noted at several plants while collecting samples. Freedman (8) relates that oyster spoilage is retarded if microbial counts are reduced.

SUMMARY

Twenty eight production lots of commercially packed oysters were analyzed for free liquid content on day of pack and 7 and 14 days post-packing. Free liquid in retail containers of fresh oysters has

TABLE 6

Classification of Commercial Samples by Free Liquid Volume on Day of Pack, Free Liquid Volume on Day 14, and Percent Free Liquid Salt (NaCl): 4X2 Contingency Table.

Percent Free Liquid Volume		Percent Free Liquid Salt (NaCl)	
On Day of Pack	On Day 14	High	Low
High	High	3	8
High	Low	0	3
Low	High	1	2
Low	Low	10	1

Chi-Square = 12.97, 3df
P < .005

"High" and "Low" designate samples above or below the class median.

TABLE 7

pH of CFR and Paired Commercial Samples on Day 7 and Day 14 After Packing.

		Pair #1	Pair #2	Pair #3	Pair #4	Pair #5	X
Day 7	CFR	6.11	6.15	6.37	6.22	6.41	6.23
	Commercial	6.13	6.36	6.71	6.50	6.43	6.43
Day 14	CFR	5.86	6.00	6.04	5.86	5.96	5.94
	Commercial	5.98	6.17	6.49	6.28	5.99	6.18

traditionally been considered to be the cumulative end product of oyster "bleeding" or "drip loss" after packing, but 21 of these lots reflected a decrease in fluid content between day of pack and day 7, and 14 of the lots contained a greater volume of free liquid when packed than two weeks after packing. An inverse relationship between salt content and free liquid volume was also observed. In general,

commercial samples with an elevated free liquid volume on day of pack were less saline than low-fluid content samples and vice-versa. These and other observations were indicative of water inclusion when many of the lots were packed. Samples of oysters known to comply with Code of Federal Regulations processing criteria were obtained from five of the lots. Comparison with commercial samples from these same lots revealed substantial differences in salinity and day of pack free liquid content in four of five instances.

Standards of identity in the Code of Federal Regulations are ordinarily adopted in response to a need to protect both the consumer and industry from unfair practices. Identity standards afford the consumer a measure of protection against deceptive merchandizing, and help shield members of industry from the economic pressures of competing with substandard, "look alike" product in the marketplace. The Federal Code alone, however, is insufficient in the case of fresh oysters in that compliance cannot be verified once oysters are processed and packed, and additional standards are necessary to fully implement the code's consumer protection intent. Florida responded to this need in 1969 by establishing a maximum water content standard at the consumer level. Data collected and observations made during this study underscore a continuing need for the standard.

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