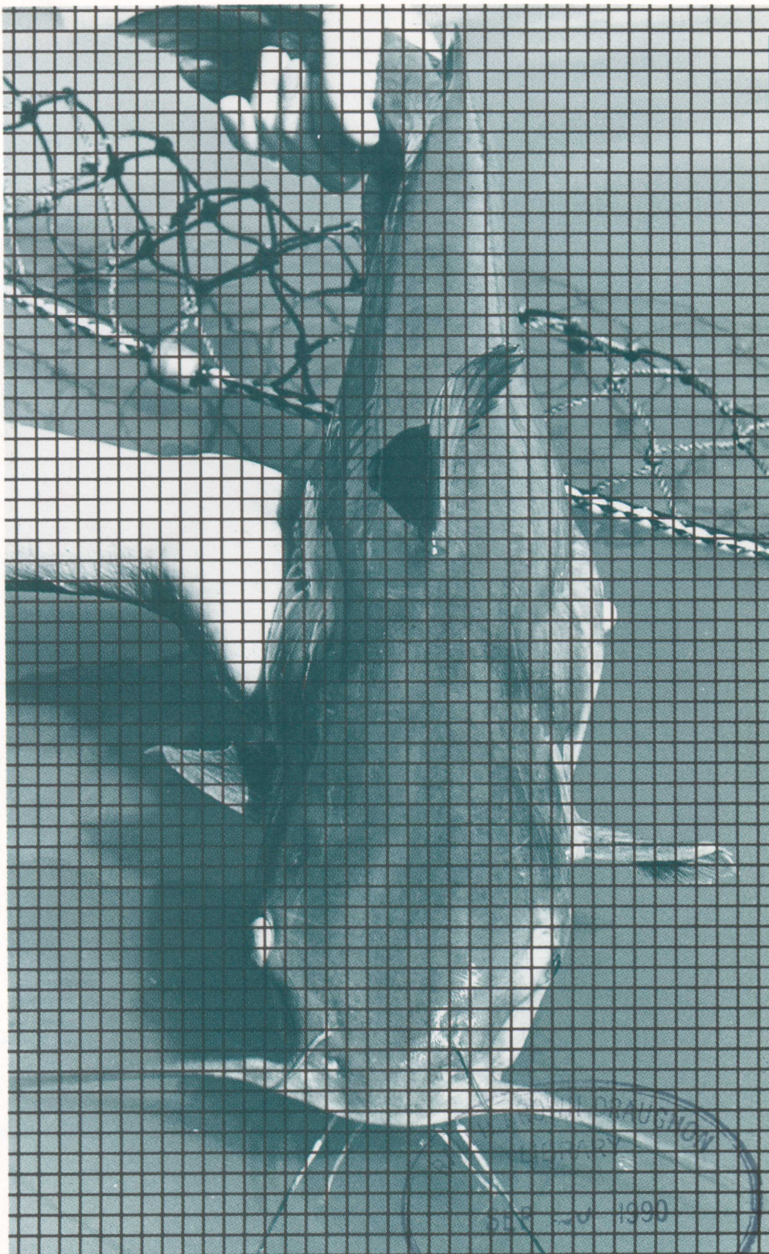
Determining the economic effects of off-flavor in farm-raised catfish



Bulletin 583
Alabama Agricultural Experiment Station
Lowell T. Frobish, Director

March 1987
Auburn University
Auburn University, Alabama

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FIRST PRINTING 3M, MARCH 1987

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DETERMINING THE ECONOMIC EFFECTS OF OFF-FLAVOR IN FARM-RAISED CATFISH

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INTRODUCTION

THE PRODUCTION of farm-raised catfish is a growing industry in the Southeast, generating additional farm revenues and spurring new developments and growth in the processing/marketing sector, and providing a new commodity for consumers.

While many of the technical production problems have been solved for farm raised catfish, a recurrent problem that has caused a great deal of concern is that of off-flavor. Statistics from Mississippi during 1985 show that 8.9 to 33.4 percent of the foodsize fish maintained in inventory by catfish producers could not be marketed on the desired harvest date due to off-flavor, table 1. This amount varied throughout the year and was particularly acute from July through November. During July to September of 1983 and 1984, over 50 percent of the catfish ponds evaluated in a study area of western Alabama were unharvestable at the time of sampling because of off-flavor (9).

Off-flavor affects the producer, processor, and consumer sectors of the catfish industry, but the nature of these effects has not been systematically analyzed, discussed, or quantified in an economic sense. It was not the intention of this study to provide a comprehensive examination of the economic impacts of off-flavor, but to look at the effect at one level of the industry, short-run aggregate farm revenues. This bulletin begins with a brief description of the catfish industry and the problem of off-flavor. Next is a general descriptive analysis of the economic issues associated with off-flavor, which identifies possible impacts to various sectors and levels of the industry. By identifying the economic issues at the various sectors and levels of the catfish industry, it is hoped this study will provide a framework for additional discussion and analysis. While recognizing the economic

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TABLE 1. AMOUNT OF FOODSIZE FISH NOT MARKETABLE DUE TO OFF-FLAVOR AND MAINTAINED AS INVENTORY BY CATFISH PRODUCERS

Month and year	Total foodsize fish inventory	Off-flavor not marketable	Inventory not marketable
	Thou. lb.	*Thou. lb.*	*Pct.*
January 1985	86,112	12,389	8.9
April 1985	45,758	4,053	10.8
July 1985	72,106	7,808	33.4
October 1985	120,202	40,184	14.4
January 1986	84,540	10,674	12.6
July 1986	64,926	13,994	21.6

Source: "Catfish." Mississippi Crop and Livestock Reporting Service. (various issues)

importance of off-flavor to the entire industry, the emphasis of this bulletin is the effect of off-flavor on aggregate farm revenues in the short-run.

THE CATFISH INDUSTRY

The catfish industry, defined here as the producing, processing, and distributing of pond-raised channel catfish for the retail market, has been characterized in recent years by steady growth. In February 1981, the total water surface devoted to catfish production was 63,050 acres (*18*). By October 1985, Mississippi and Alabama alone had 76,400 acres in catfish production. The live weight of fish delivered for processing increased from 40.6 million pounds in 1979 to 191.9 million in 1985 (*18,19*). In Mississippi, the 1985 farm value of catfish was estimated to be a record $202 million (*2*).

Preparing these fish for the retail market has sparked investment in the processing industry as well. As recently as 1967-68, virtually all pond-raised fish were sold live, either as fingerling stock or as adult fish for fee fishing ponds or brood stock for breeding purposes (*21*). In 1980, processing plant capacity was 85.8 million pounds per year on a live weight basis and by 1983 annual processing capacity had expanded to about 191 million pounds based on a 5-day work week and 8-hour shift each day (*1*). Delta Catfish Processing, Inc., the largest catfish processor in North America, reported sales of about $50 million in 1985 and had an annual payroll of more than $10 million (*3*).

Future prospects for increased growth appear to be bright as the U.S. public increases its consumption of fish and fish products. Per capita consumption of fishery products has increased 20 percent since 1967, with per capita consumption of fresh and frozen fish at 5.2 pounds in 1983 (*20*). A leveling off of fish supplied to markets through the capture fishery indicates an increased reliance on farm-raised fish. Aquaculture has the added advantage of being in a better position to insure uniform quality and a consistent supply.

The catfish industry in particular is well positioned to take advantage of this situation. The technological problems of production have been largely resolved, the enterprise is feasible and profitable with proper management, and consumer acceptance of catfish has grown both for in-home sales and in added demand from fast food outlets. The entry of Church's, a fast-food type restaurant, in the marketing of catfish products in its retail operations is indicative of this trend. In addition, the poor profitability of row crops, current lower feed prices, and reduced construction costs due to lower energy prices indicate increased profits to the fish farmer and may spur new entries into production (22). This addition to productive capacity may promote future consumer demand by lowering prices.

PROBLEM OF OFF-FLAVOR

An area that causes concern in the catfish industry is the persistent problem of off-flavor. Off-flavor occurs when catfish absorb flavor compounds, produced by pond organisms, that render the fish unmarketable for the period in which the off-flavor exists. Results of an Alabama Agricultural Experiment Station study indicate that the compound geosmin is the principal cause of most off-flavor in catfish ponds during the summer months (*11*). At present, there are no cost-effective control methods that are satisfactory for most producers. Although off-flavor does not permanently damage the product, it does represent an effective supply control that keeps the product in the farmer's inventory until the fish are marketable. The farmer maintains the stock until the off-flavor disappears, a matter of months if kept in the pond or a few days if placed in clean water. Off-flavor is detected before harvest by taste testers employed by the processor.

The uncertainty surrounding off-flavor, its causes, cures, and testing for its presence have created a great deal of concern in the industry. In 1980, the Research Committee of the Catfish Farmers of America trade organization identified off-flavor as the most serious problem the industry faced (*11*). The concern was due to: (1) the high rate of occurrence, table 1; (2) the damage off-flavor can have on consumer confidence; and, (3) the lack of control measures for off-flavor. Alabama producers, responding to a 1984 survey, ranked off-flavor as their most financially damaging risk (5).

ECONOMIC ISSUES OF OFF-FLAVOR

The catfish industry is a multi-stage system composed of producers, processors, consumers, and other participants (including live-haulers, retailers, and pay-lake operators). Characteristics of the catfish market, figure 1, include:

1. A significant amount of the total production available for processing may be unharvested in any given month or season, table 1.
2. The vast majority of the farm produced supply is sold directly to processors, the alternatives being direct sales and live haulers.
3. No close substitutes for catfish exist at the processing level.
4. A commodity that is homogenous at the producer level and heterogenous at the retail level; this implies that producers are price takers and cannot effectively discriminate in their markets.

Off-flavor is portrayed in figure 1 as a loop in the producing sector. A pond may be available for harvesting, but due to off-flavor, the fish are cycled back into the production process and held in inventory until they can be marketed. This supply restriction, imposed by off-flavor, has economic impacts at all three stages of the system.

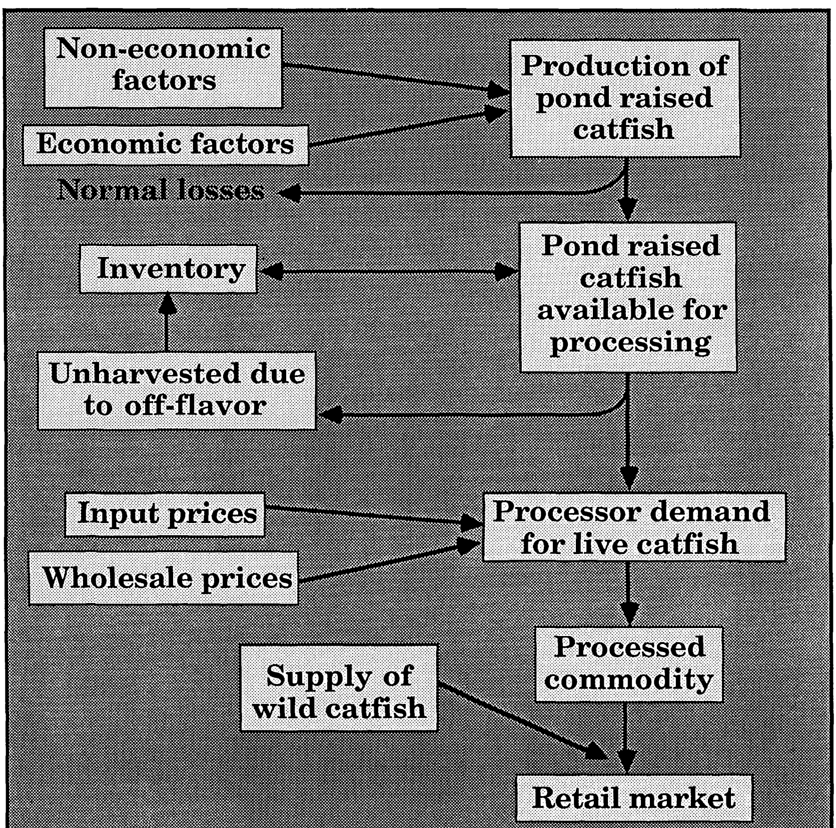

FIG. 1. Simple diagram of the catfish market.

Impact on Consumers

The economic effect of off-flavor on consumers of catfish is largely in the form of higher prices that result when the amount of the commodity marketed is less than possible given total production. Despite the precautions, some off-flavor fish may still reach market. Thus, there is some risk of losing consumers who pay top dollar for good catfish, but get low quality associated with off-flavor. An effective prevention and control of off-flavor will benefit individual consumers by increasing the amount marketed at any given time and by reducing the risk of purchasing an off- flavor product. The aggregate effect would be increased consumer confidence and acceptability, a vital factor for the industry's future growth.

Impact on Processors

The economic problem of the processor is to choose the quantity of catfish under a cost constraint that maximizes profits. At the firm level, off-flavor clearly harms processors by keeping input prices up and introducing a degree of uncertainty, particularly in scheduling harvests and anticipating amounts entering the plant. Individual firms also face a cost in the wage that is paid to the taste testers. At the aggregate level, off-flavor reduces the efficiency of the processing/marketing sector. An effective prevention or control of off-flavor will benefit the processing sector through efficiency improvements that result from a more dependable supply of on-flavor fish. Harvest schedules and labor assignments at the plant will not be disrupted and orders filled without delay. Input costs may be reduced and individual firms would no longer have to employ the taste testers.

Impact on Producers

Producers were the primary focus of this study. Within this sector, attention was focused on the costs associated with off-flavor. Three levels of costs due to off-flavor that affect producers have been identified: (1) the micro-level costs to individual producers, (2) the disequilibrium in the market caused by reduced marketings, and (3) the short-run aggregate gross farm revenue effects.

Micro-Level Costs

At the micro, or firm level, there may be direct and indirect costs to individual producers from off-flavor. These are the costs that most readily come to mind when people in the industry discuss off-flavor. As described earlier, off-flavor forces the farmer to maintain an inventory of market ready foodsize fish. The direct costs of holding this commodity include:

1. The opportunity cost of the delayed income. Since the producer cannot harvest and sell the fish when expected, receipt of payment is delayed.

2. The additional feed costs. The fish held back must be fed. The cost of this feeding may be somewhat offset by the additional weight gain that occurs in the growing season. The fish, however, may grow beyond the size that processors prefer and larger fish have poorer feed conversion ratios *(10)*. Outside of the growing season, the additional feed is merely a maintenance diet.

3. The extra risk of maintaining the inventory. The longer market ready fish are held, the greater the opportunity for disease, predation, or other losses normally encountered in production.

There also may be indirect costs to individual producers. The farmer may be bumped from the processor's harvesting schedule, meaning that even if the pond comes back on flavor in a short time, the inventory may have to be maintained until his "turn" comes around again. In addition, the presence of off-flavor limits the producer's power to decide when to market his own fish.

Some producers consider these costs high enough that they are willing to construct holding facilities to purge the fish of off- flavor by placing them in clean water for several days. For these producers, eliminating the risk and being able to harvest as scheduled must more than compensate, at the margin, the weight loss that occurs plus the construction and maintenance of these holding facilities.

A technology that effectively prevents or controls off-flavor will, for individual producers, reduce some of these costs, risks, and uncertainties that are connected with off-flavor problems, as well as enhance their ability to market their product when they choose.

Disequilibrium Costs

The second level of costs to producers results when the market is in disequilibrium. This is an aggregate cost to producers and is best described by figure 2. In the graph, S2 represents the short run supply curve of current production, with total quantity Q2, and S1 is the short run amount marketed, quantity equal to Q1. Q2 - Q1 is the amount withheld from the market due to off-flavor. S(LR) is the long run supply curve for the industry. Producers respond to price FP, and as they plan the next production cycle, produce out to the intersection of the current price and the long run supply curve, or Q*. This results in overproduction, given the demand, and there will be subsequent price drops. This type of disequilibrium results in the pre-

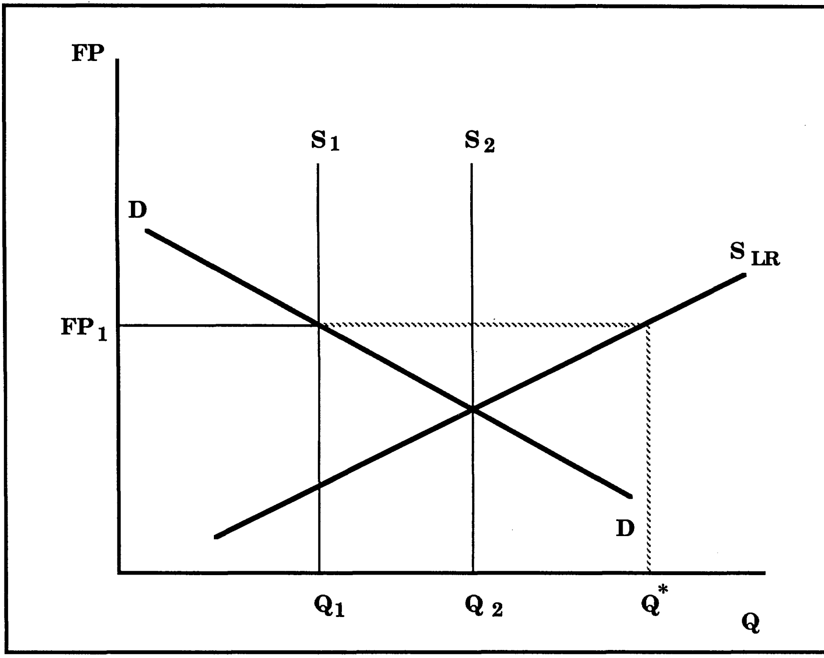

FIG. 2. The disequilibrium effects of off-flavor in the producer sector.

vailing cycles of over/under production and price swings that impose some additional aggregate costs to producers in general.

Revenue Effects

The third level of costs to producers, and the focus of this report, is the short-run aggregate gross farm revenue effect. An empirical analysis was conducted to examine the general perception that off-flavor reduces farm revenue to the industry as a whole.

Figure 3 illustrates the aggregate effect of off-flavor to farm revenues. The supply curves are depicted as perfectly inelastic or parallel to the price axis. In the short run and if the supply of live catfish is totally composed of farm-raised catfish, assuming perfectly inelastic supply curves may be justified. Once established, the inputs to catfish production, especially land, cannot readily substitute in the production of other commodities. The capital has been committed for the long term and the time required for adjustment is quite long. Catfish farmers generally attempt to maximize production and are interested in marketing an entire crop at harvest. Once the fish ponds are stocked and normal losses accounted for, the supply is relatively fixed.

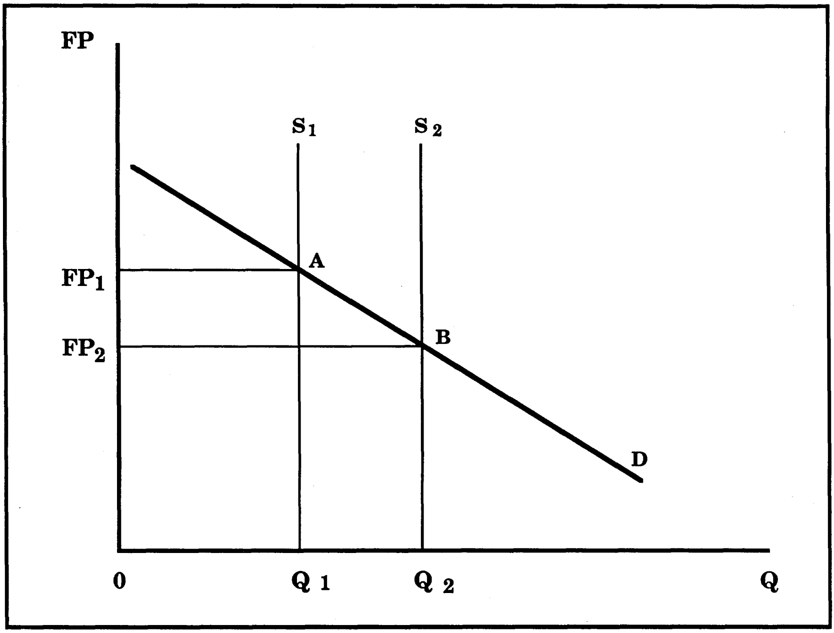

FIG. 3. Short-run farm level market for live catfish.

The demand for catfish at the farm level comes mainly from processors. Currently, about 90 percent of the farm output is sold to local processing plants (*4*). The processors are in turn influenced by consumer demand at the retail level.

In the scenario of figure 3, the market is currently operating at point A, selling quantity Q1 with a farm price FP1. Production, however, is at Q2. Q2 - Q1 is the amount withheld due to off- flavor. Total revenue to producers is determined by the product of the appropriate price and quantity. Current revenues are FP1 times Q1 and can be depicted by the rectangle FP1-A-Q1-0. If there were no off-flavor and total production could be marketed, farm price would drop to FP2 and total revenues could be seen in the area FP2-B-Q2-0.

It cannot be determined from a graphical analysis whether this second revenue rectangle at Q2 and FP2 is greater than the first revenue rectangle at Q1 and FP1. The key issue in determining the relative sizes of these two revenues is the slope, or elasticity, of the demand curve. Price elasticity of demand is defined to be the percentage change in quantity demanded resulting from a 1 percent change in price. In the analysis, this price change was assumed to be a result of the increase in the quantity of live catfish marketed given a technology that prevents or controls off-flavor.

If the demand curve in figure 3 is steep enough to be considered inelastic (if the absolute value of the elasticity is less than 1), increasing the amount marketed by effectively preventing or controlling off-flavor and moving from Q1 to Q2 will drive the farm price down so far that the increased amount sold will not compensate for the price drop and aggregate farm revenues will actually decline. In a situation of inelastic demand, then, the presence of off-flavor would serve to keep farm prices and total farm revenues higher by reducing the amount marketed.

It also should be kept in mind that the quality improvement occurring when off-flavor fish are kept off the market may raise the new equilibrium price above that expected. Price (*16*) and Nguyen and Vo (*15*) presented this issue in their discussion of discarding low quality produce. Basically, the supply shift caused by withholding inferior products from the market is more than compensated for by the rise in price due to higher quality. As recognized by the trade association, putting off-flavor fish on the market would damage consumer confidence in the product and negatively affect demand.

Many, if not most, agricultural commodities are characterized by a demand that is price inelastic. Government farm programs that attempt to raise total farm revenues by controlling supply recognize this phenomenon. Keeping in mind that we are describing catfish producers in aggregate and total revenues at the industry level (individual producers obviously will have reduced revenues when ponds are off-flavor), an inelastic farm level demand is plausible for two reasons. First, from the processors point of view, there are few substitutes for catfish that could be used in their processing plants. The fewer substitutes available and the more unique the commodity, the more inelastic will be the demand for the commodity. Second, the farm level demand is related to the demand for catfish at the retail level. A commodity that accounts for a small proportion of the consumer's budget tends to have less elastic demand curves. Therefore, it is conceivable that the farm level demand for catfish may be inelastic and that increasing the amount marketed by solving the problem of off-flavor would reduce total revenues to catfish producers.

This is contrary to the perception that off-flavor reduces total farm revenues by reducing marketings in the short run. Implicit in this perception is that the demand faced by catfish producers is price elastic. A precise estimate of the demand for catfish at the farm level and the associated elasticity is necessary for a more accurate assessment and evaluation of the off-flavor marketing problem. Whether the demand is elastic or inelastic is of crucial importance to formulating appropriate policy for the industry.

METHODOLOGY, DATA, AND STATISTICAL ANALYSIS

Two previous studies indicate that demand for catfish may, in fact be elastic. A study of Atlanta supermarkets in 1972 estimated a retail price elasticity at data midpoints of about -2.5 (*17*). Kinnucan (*7*) estimated demand at the wholesale level to be generally elastic, but during certain seasons of the production year, it may be inelastic.

A model of the farm level demand for live catfish was developed for this study and estimated using a modified two-stage, least squares procedure. Data to estimate the model came from six individual processing plants. Thus, there were six estimates of the demand elasticity. Since the data were from a cross-sectional time series of individual processing plants, a simple procedure to take into account the variability of the entire data set was used to adjust results from the two stage analysis. Adjusted elasticities were calculated from these coefficients and weighted by the market shares of the individual plants to estimate an industry-wide, farm level demand elasticity. This weighted average was then used to evaluate potential revenue changes resulting from off-flavor.

MODELING FARM LEVEL DEMAND

Farm level demand was modeled using a linear function taking the form:

(1) $Q_t = a_0 + a_1 FP_t + a_2SUBP_t + a_3SPNG_t + a_4INC_t + a_5MEAT_t + a_6FISH_t + E_t$

where:

Q_t = the total processed quantity sold in a given month adjusted for changes in inventory and per million population.

FP_t = farm price per pound received by producers, live weight basis.

$SUBP_t$ = weighted average of the price received for the two processed commodities by the five other plants.

$SPNG_t$ = spring dummy variable, the months February, March, April.

INC_t = personal income in constant terms per million population.

$MEAT_t$ = the monthly meat Consumer Price Index (CPI) deflated by CPI all items.

$FISH_t$ = the monthly fish CPI deflated by CPI all items.

E_t = a random error term.

Farm level demand elasticities were calculated for each plant by using the coefficient of the farm price obtained from the model and the mean values of FP and Q from the data set.

DATA

To estimate the model, data from individual processing firms were used. These data appear in an aggregate form in the USDA's monthly Catfish Report published by the National Agricultural Statistical Service. The disaggregated data were made available for this study with the proviso that individual firms would have their anonymity guaranteed.

Monthly data from six firms were available, generally covering the period January 1980 through December 1983. Data sets were complete for three firms, with one firm ceasing to report before the end of the period and two beginning to report after January 1980. The six plants represented approximately 80 percent of the industry output over the sample period. The data of interest are the monthly figures on the liveweight amount in pounds delivered for processing, the price per pound paid to growers, the amount sold as ice pack and the price received, the amount sold as individually quick frozen and the price received, and the end of month inventory.

ESTIMATING THE MODEL

The model describes a derived farm level demand as generated by the processors for live catfish. The disaggregated data provide rather a unique look into the farm level demand in this particular industry, but because of its cross-sectional time series nature it posed some additional estimation problems. The data were initially evaluated under this model using an ordinary least squares (OLS) procedure. This type of single equation estimation may be appropriate under perfect competition, where individual processing firms cannot influence the price of their inputs, specifically live catfish. In this situation, processors face a perfectly elastic supply curve for live catfish with the farm price and quantity determined independently.

A single equation estimation may not be appropriate for the catfish processing industry, however. The industry may operate under conditions of imperfect competition, with the farm price and quantity jointly determined, indicating that some type of simultaneous equation estimation may be more appropriate (8). Under these conditions, a two-stage, least squares (TSLS) procedure for estimating simultaneous equations is appropriate.

An additional estimation issue requiring consideration was serial correlation in the error terms. This problem became evident when equation (1) was estimated by the OLS procedure. Serial correlation arises when the disturbance term of one observation is correlated with the disturbance term of another observation. It is a common problem with time series data of the type used in this analysis. To correct for the problem, a second estimator, an autoregressive maximum likelihood procedure, was used. In addition, the TSLS estimates were obtained using a procedure for estimating simultaneous equations in the presence of serial correlation (6).

In implementing the TSLS procedure, an instrument was constructed for the endogenous variable, farm price, using additional predetermined and exogenous variables that describe the supply influences. These variables were the farm price lagged one period, the price of soybeans, and a trend variable. The farm price was estimated in the first stage using these variables plus, following Fair (6), the predetermined variables from the original equation lagged one period, and a lagged dependent variable.

The first stage, then, is calculated as follows:

$$(2)\ FP_t = k_0 + k_1FP_{t-1} + k_2SOYB_t + k_3T_t + k_4Q_{t-1} + k_5SUBP_{t-1} + k_6SPNG_{t-1} + k_tINC_{t-1} + k_8MEAT_{t-1} + k_9FISH_{t-1} + u_t$$

where the as yet undefined variables SOYB and T are the price of soybeans and trend, respectively.

The predicted farm price from this first stage then acted as the instrument for FP in the second stage, which used an autoregressive maximum likelihood procedure to estimate the equation originally specified.

Table 2 presents the results from the three estimation procedures. The R2, a goodness of fit indicator, measures the percentage of the variation in each plant's purchases that can be explained by the variation in the specified variables. The R2's in the OLS estimates ranged from 0.39 for plant F to 0.74 for plant D. The other four plants had R2 in the 0.51 to 0.63 range. The results from the two stage procedure were the basis for further analysis.

The farm price coefficient was of primary interest in the analysis since it was used to calculate the elasticity. As seen in table 2, this coefficient is negative for all firms, as expected, and is significantly different from zero for three firms, B, C, and E. Firm A's farm price coefficient has a p-value of between 0.05 and 0.10, providing weak evidence that it is significantly different from zero. Firm A was unique in that it was on a downward trend throughout the data period in its liveweight purchases and payments to farmers, and ceased operations before the end of 1983. The farm price coefficient cannot

TABLE 2. COEFFICIENT ESTIMATES AND STANDARD ERRORS OF THE CATFISH DEMAND EQUATION USING THREE ESTIMATORS

OLS/	Variables								
FIRM	Intercept	FP	SUBP	SPNG	INC	MEAT	FISH	R2	D.W.
A:	34084	-226.4	94.6	480	-11973	-3026	11973	0.51	1.3
	(13659)	(81.9)	(71.8)	(301)	(2998)	(3647)	(5571)		
B:	14037	-132.8	-2.6	516	-3643	-173	3541	0.60	2.4
	(7537)	(44.5)	(37.8)	(177)	(1600)	(2148)	(3340)		
C:	25152	-350.9	201	982	-5816	-428	-613	0.55	1.8
	(13624)	(71.9)	(69.5)	(318)	(2939)	(3605)	(5794)		
D:	21306	-26.6	3.5	226	-3668	3361	-7227	0.74	1.4
	(14962)	(56.7)	(58.2)	(214)	(2716)	(4584)	(3488)		
E:	6142	-533.6	-133.5	-976	1995	-11480	13445	0.63	1.5
	(35496)	(184.2)	(116.2)	(729)	(6619)	(12623)	(11651)		
F:	33231	-14.8	-108.3	956	-7055	-5440	6480	0.39	2.3
	(18235)	(95.2)	(93.1)	(452)	(3872)	(5112)	(8166)		
AUTO/									
FIRM	Constant	FP	SUBP	SPNG	INC	MEAT	FISH		D.W
A:	24239	-200.6	64.2	245	-9683	-1309	14485		1.8
	(15340)	(94.9)	(77.1)	(280)	(3430)	(4259)	5632)		
B:	14769	-139.9	4.5	579	-3710	-386	3194		2.1
	(5790)	(33.8)	(29.8)	(146)	(1224)	(1631)	(2702)		
C:	24778	-340.4	194.6	976	-5737	-424	-535		1.9
	(13587)	(72.5)	(68.6)	(300)	(2934)	(3610)	(5535)		
D:	32473	-25.3	-10.7	139	-6255	-1765	-3932		2.0
	(13799)	(57.8)	(46.1)	(148)	(2493)	(4420)	(2782)		
E:	1295	-530.0	-130.7	-1069	3275	-12592	14004		2.0
	(25252)	(180.9)	(104.8)	(592)	(6739)	(13082)	(10174)		
F:	34340	-34.1	-91.7	1066	-7143	-6110	6120		2.0
	(14795)	(77.6)	(78.7)	(394)	(3130)	(4123)	(6980)		
2SLS/									
FIRM	Intercept	FP	SUBP	SPNG	INC	MEAT	FISH		D.W
A:	26596	-163.4*	38.1	209	-10035	-948	13712		1.9
	(15541)	(103.2)	(81.6)	(284)	(3441)	(4208)	(5715)		
B:	14019	-142.4*	5.4	558	-3554	-126	3127		2.1
	(6051)	(39.1)	(33.2)	(150)	(1283)	(1690)	(2804)		
C:	21122	-387.4*	192.9	681	-6113	-1059	4805		1.9
	(12878)	(71.5)	(61.6)	(277)	(2696)	(3357)	(5338)		
D:	33996	-36.9	-17.3	130	-6442	-2131	-3908		2.0
	(14655)	(68.0)	(49.4)	(151)	(2565)	(4604)	(2778)		
E:	-11869	-619.7*	-89.3	-754	6768	-9168	11251		1.9
	(34900)	(214.6)	(117.0)	(615)	(6881)	(12501)	(10161)		
F:	32766	-67.3	-65.9	1104	-6737	-6140	5824		2.0
	(14905)	(86.3)	(82.8)	(388)	(3163)	(4071)	(6952)		

be considered different from zero for D and F, the smallest and largest of the six firms, respectively, in terms of liveweight purchases and payments to farmers. As the smallest and largest, the behavior of these two plants may not be accurately portrayed in the model. Their purchase and pricing behavior may be different from the other plants. In addition, plant D, with only 22 observations, may be subject to a small sample bias. For illustrative purposes, the subsequent analyses were conducted for all six plants, keeping in mind that plants D and F had statistically insignificant coefficients for the farm price.

A second variable of interest was the income variable. In the modified two-stage least squares results, the coefficient of this variable was negative and significant in five of the six plants. An interesting implication of this result is that as incomes rise (all other things being equal), the amount of catfish purchased decreases. This is consistent with a perception among some members of the consuming public that catfish is typically a commodity purchased by low income consumers. Under this perception and as indicated in the negative coefficient, the consumption of catfish would decrease as family or personal income increases. Altering the perception that catfish is a low income food commodity may be an area in which the catfish industry can direct some of its efforts.

DEMAND ELASTICITIES

As explained earlier, the demand elasticity is especially important in the analysis of the farm revenue impacts of off- flavor. As seen in figure 4, a precise estimate of the elasticity is crucial to the analysis of farm revenue changes. The graph shows the percentage change in total farm revenue associated with some demand elasticity. The most crucial changes occur for an elasticity of between -0.5 and -2.0.

The demand elasticity (Ed) was calculated using the formula:

$$Ed = B \times (FP/Q).$$

where B = the coefficient of the farm price from the regressions, FP = mean farm price, and Q = mean quantity of fish.

Elasticities are all negative, as expected, and with the exception of firm F, all are in the price elastic range, table 3.

Since the equation estimated is assumed to be linear in the original variables, the estimated elasticity as defined above is partially constructed from a ratio of random variables, farm price, and quantity. Considering the importance of this estimate to the analysis, exact confidence intervals for these elasticities were constructed using the procedure developed by Miller et al. *(13)*, table 3.

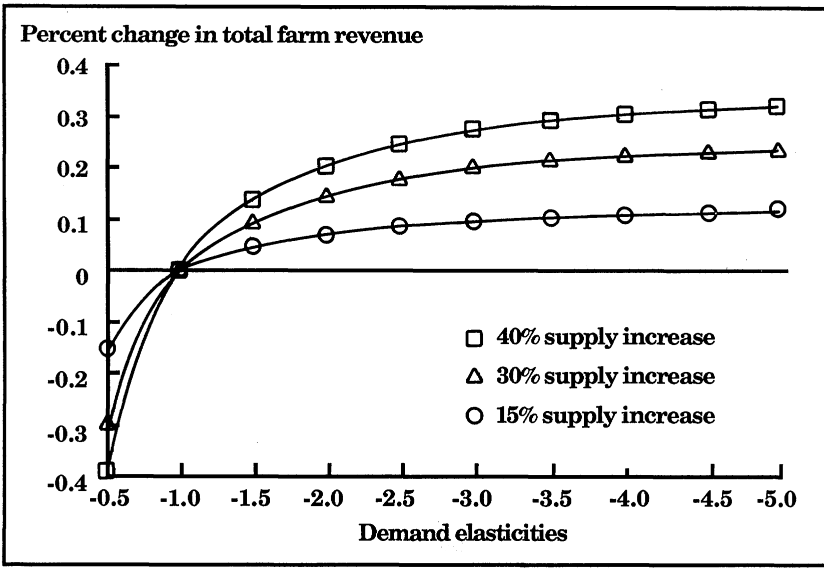

FIG. 4. Relationship between demand elasticities and percentage changes in total farm revenue given various percentage increases in supply.

Assuming that the farm price and quantity variables are normally distributed, the endpoints of the confidence interval are those values of R for which:

$$R^2[z_2 - t^2s_2] - 2R(z_1z_2) + z_1 - (t^2)s_1 = 0$$

In our problem:

z_1 = BiFP
z_2 = Q
s_1 = (FP) (variance of Bi)
s_2 = s variance of the estimate
$(t)^2$ = the squared value of the upper a/2 percentage point of the tabular t-distribution with appropriate degrees of freedom.
d.f = T - K - 1 K = 6

TABLE 3. DEMAND ELASTICITY, CONFIDENCE INTERVAL, B*, AND ADJUSTED ELASTICITY FOR EACH FIRM

Firm	Demand elasticity	95 percent confidence interval	B*	Adjusted elasticity
A	-1.4	0.4 to -4.0	-181.7	-1.6
B	-1.9	-0.8 to -4.1	-146.7	-1.9
C	-3.5	-1.9 to -7.5	-366.3	-3.3
D	-1.2	3.9 to -7.4	-62.4	-2.0
E	-3.6	-1.0 to -8.3	-392.1	-2.3
F	-0.4	0.6 to -1.5	-99.5	-0.5

Solving the quadratic formula yields the confidence interval about the calculated demand elasticity. All the firms were evaluated at the 95 percent confidence level. The plants that showed the highest degree of statistical significance in the farm price coefficient had point estimates of the elasticity well into the elastic range and confidence intervals that were widely skewed in that direction. Two of these plants, C and E, accounted for over 40 percent of the industry output of fish represented by the data. Plant A also had a point estimate that is elastic, but its confidence interval included the inelastic as well as positive values, inconsistent with expectations. Plant D, while having a point estimate that was price elastic, had a confidence interval so broad as to drastically reduce any meaning to the estimate. Plant F's estimate was price inelastic and its confidence interval is less skewed to the elastic range than the other plants.

The procedure for calculating exact confidence intervals assumed that the farm price and quantity are normally distributed random variables. This assumption, together with a 95 percent probability, may be too restrictive for the analysis. Nevertheless, these confidence intervals indicate that caution must be exercised when interpreting the calculated price elasticity of demand.

QUASI-POOLED ESTIMATES

As mentioned above, the data are from a cross-sectional time series, so pooling the data and estimating a single equation were also examined. An F-test was constructed using the restricted and unrestricted residual sum of squares from the regressions. The F- tests were highly significant, indicating that pooling could not take place.

Maddala (*12*, p. 333) suggests an alternative to pooling in which the appropriate coefficients are adjusted toward a common mean. According to Maddala, "the idea is to bear all the available information for the estimation of each regression parameter while at the same time allowing for potential differences that may exist between the different regressions." The procedure is to calculate a B*, an adjusted farm price coefficient, providing an estimate that is somewhere between pooling all the data and estimating a single equation for all six plants, and estimating each firm individually. Such a procedure would be appropriate in this case where some commonalities are likely among the firms.

B* is calculated using the following formula:

$$B^* = \frac{W1Bi + W2B}{W1 + W2}$$

where:
Bi = estimated coefficient for the ith plant
B = the mean of the estimated Bi's
W1 = 1/estimated variance of Bi
W2 = (N/N-1)(1/t) where:
t = (1/N-1)(sum(Bi -B)2) - (1/N)sum(var. Bi)
N = number of parameters in the model (=6)

The B*'s for each plant and corresponding elasticities are given in table 3. Since these adjusted elasticities have incorporated the variability of the entire data set, they will be used in further analysis. These adjusted elasticities, weighted by individual plant market shares, average -1.8.

RESULTS

The information presented in the preceding section provides the means to analyze changes in short-run aggregate farm revenue that may have occurred in the absence of off-flavor, as if an effective prevention or control for off-flavor existed. In this section, both industry-wide and distributional effects are considered.

INDUSTRY-WIDE FARM REVENUE EFFECTS

The weighted demand elasticity of -1.8 is used in the following relationship to determine the elasticity of total revenue (Etr) with respect to quantity: Etr. = 1 + 1/E

The elasticity of total revenue, defined to be the percentage change in total revenue given a 1 percent change in quantity, is 0.4.

Point estimates of elasticity are generally considered valid only for small changes in price. By assuming this 0.4 elasticity for total revenue does not change with movement along the demand curve, it is implicit that the demand elasticity of -1.8 is also constant. For simplicity, this was assumed to be the case.

In the analysis, a 15 percent increase in the marketing of live catfish under this new technology was assumed. This is approximately the yearly average for the percentage of fish held in farmers inventories that were unmarketable due to off-flavor as reported in the Mississippi data, and is well below the 50 percent reported during the summer months in the Alabama survey. It also reflects the uncertainties regarding the current status of off-flavor research in terms of costs, potential effective controls, and potential adoption.

Using the estimate of the elasticity of total revenues, total revenues could be increased by 6 percent with a 15 percent increase in quantities available for processing. Recognizing that over the data period considered, these six firms accounted for some 80 percent of the total sales of live catfish to processors, these percent changes in total revenue can be considered to reflect industry conditions. Applying these percentages to the farm revenue data from 1975 to 1985 provides a rough estimate of the cost to the industry in terms of revenues not received, figure 4. In 1985, for instance, these calculations show an increase in total farm revenues of some $8.3 million if the amount marketed increased by 15 percent, table 4. A more meaningful interpretation places this figure on a per capita basis. The only published data available show 1,095 catfish operations in 1981. Applying this number to our 1981 estimate of revenue change shows an estimated loss of potential revenue of $2,115 per catfish operation. In comparison, the Alabama survey (5) reported average revenue losses due to off-flavor for the same year of $1,136 among the farmers sampled. Since Alabama catfish farms are generally smaller than Mississippi farms, where the majority of production occurs, this estimate of the average revenue loss appears reasonable.

DISTRIBUTIONAL EFFECTS

The analysis can be extended to examine the possible effects to smaller groups of farmers. Each processing plant generates farm revenues in its payments to producers for live catfish. At the firm level, farm revenues can be calculated directly from the data based on each processor's monthly purchases and prices paid. The changes in farm revenue generated by individual processors can be examined by calculating a farm price response surface for each plant.

TABLE 4. ESTIMATED CHANGES IN INDUSTRY WIDE FARM REVENUES WITH A 15% INCREASE IN THE AMOUNT OF CATFISH AVAILABLE FOR PROCESSING

Year	Total amount sold to processors[1]	Average farm price/lb.	Undeflated dollars		
			Farm revenue	Revenue change	Potential farm revenue
	Mil. lb.	*Cents*	*Millions*	*Millions*	*Millions*
1975	16.1	48.5	7.8	0.5	8.3
1976	19.0	52.8	10.0	0.6	10.6
1977	22.1	58.0	12.8	0.8	13.6
1978	30.2	54.6	16.5	1.0	17.5
1979	40.6	61.0	24.9	1.5	26.4
1980	46.5	67.6	31.4	1.9	33.3
1981	60.6	63.7	38.6	2.3	40.9
1982	99.3	55.0	54.7	3.3	57.9
1983	137.3	61.1	83.8	5.0	88.9
1984	154.3	69.3	107.0	6.4	113.4
1985	191.2	72.5	138.9	8.3	147.3

[1]Source: "Catfish." Crop Reporting Board, Statistical Reporting Service, USDA.

A farm price response surface can be calculated by first estimating a "collapsed" constant and writing new equations for each plant. These equations are of the form:

$$Q = a - B^{*}FP$$

"a" is calculated by substituting into the above formula the adjusted farm price coefficient, B*, and the mean values for farm price and quantity from the data set.

A new farm price can now be determined at any quantity within the data range. Again, assuming a 15 percent increase in the quantity marketed following the development of a technology that effectively prevents or controls off-flavor, the effects on farm revenues, or payments by these individual processors, can be evaluated. Percent changes are derived by comparing the product of this determined farm price and quantity with the product of the mean farm price and quantity.

Percent revenue changes for the six firms range from -17.0 percent to 9.6 percent, table 5.

Using the original data, the additional payments by these processors to producers (farm revenue) range from -8.7 million to 3.3 million over the 4-year sample period. With the exception of plant F, producers supplying each plant gain from the prevention or control of off-flavor, but the magnitude of the gains differ by plant. Producers supplying plant F will actually experience a decline in receipts because of the inelastic demand of this plant. However, keeping in mind that the farm price coefficient was statistically insignificant for plant F, extending the analysis to include it is useful primarily for didactic purposes, that is, it illustrates the effects of off-flavor if producers are facing an inelastic demand for live catfish. Excluding plant F, the weighted average of these percentages is 6.9 percent, which is consistent with the industry wide percent revenue change of 6.0 percent.

The distributional analysis suggests that some farmers may benefit more than others depending on the purchasing behavior of the pro-

TABLE 5. POTENTIAL INCREASES IN FARM REVENUE DUE TO THE PREVENTION OR CONTROL OF OFF-FLAVOR, BY PROCESSING PLANT, U.S. CATFISH INDUSTRY, 1980-83

Plant	Payments by plants to producers, undeflated dollars			
	Actual[1]	Potential[1]	Difference	Difference
	Millions	*Millions*	*Millions*	*Pct.*
A	32.77	34.05	1.28	3.91
B	14.99	15.86	.87	5.80
C	33.99	37.26	3.27	9.62
D	4.94	5.27	.33	6.68
E	39.34	42.37	3.03	7.70
F	51.58	42.81	-8.77	-17.00

[1]Cumulative totals for the period 1980-83.

cessor with whom they normally do business. For example, in 1981, plant A with 21 percent of the total industry market would have purchased catfish from approximately 230 producers. Under the assumptions of the analysis, each of these producers would have received $1,400 more if the prevention of off-flavor had increased their marketings by 15 percent. The approximately 208 producers selling to plant C, however, would have received an additional $3,400 each.

Figure 5 further illustrates this possible distributional effect by plotting the farm price response surface for each plant. One observation based on this graph is that larger firms tend to have flatter price response surfaces. As a consequence, producers selling catfish to plant B (a small plant) can expect to receive relatively lower prices and revenues by increasing the amount available for processing than those selling to plants C and E (larger plants). Plants A and F do not fit the pattern. As explained earlier, plant A was one of the largest plants at the beginning of the data period, but consistently lost shares and dropped out before the end of 1983, which may account for this behavior. Plant F, the largest plant, may exhibit different behavior as well.

CONCLUSIONS AND IMPLICATIONS

Off-flavor is a chronic problem that is the focus of much attention in the catfish industry. The research reported here provided a gen-

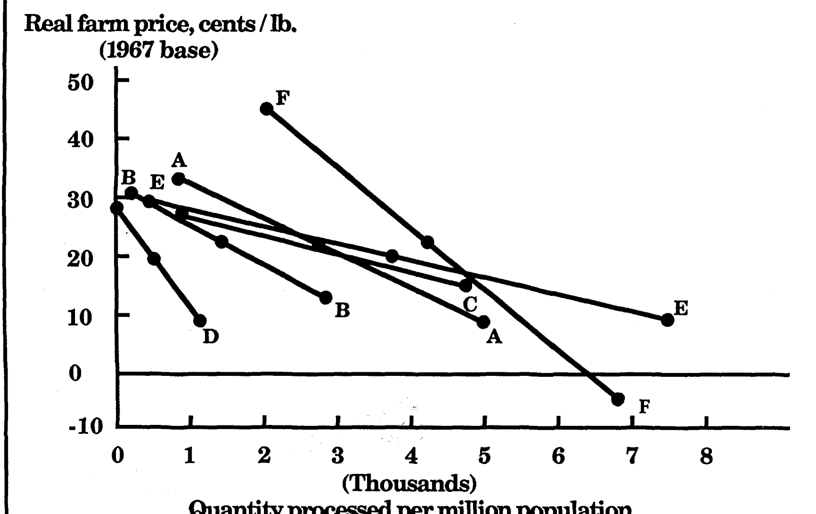

FIG. 5. Farm price response surfaces for the six catfish processing plants, based on 1980-83 data.

eral outline of the economic issues associated with off-flavor facing the consumers, processors, and producers of catfish and developed an econometric analysis of off-flavor's effect on short-run farm revenues.

The economic effect of off-flavor to consumers of catfish is largely in the form of higher prices that result when the amount of the commodity marketed is less than possible given total production. In addition, off-flavor negatively affects consumers' perceptions about quality and reduces their confidence when deciding whether to purchase catfish. Off-flavor harms processors by keeping prices up and introducing a degree of uncertainty, particularly in scheduling harvests and in anticipating the amount of live catfish entering the plant. The economic effect on producers was discussed at three levels. First were the direct costs to individual producers of holding in their ponds a market-sized fish that could not be harvested due to off-flavor. Second was the disequilibrium in the market caused by the uncertainty of not knowing the exact level of reduced marketings. Third, and the major focus of this report, was the effect on short-run aggregate farm revenues.

Recognizing the importance of the economic issues outlined, the econometric analysis developed examined aggregate farm revenues by modeling farm level demand using data supplied by six processing plants. Calculating the demand elasticity from the econometric results revealed an elastic demand for catfish at the farm level. A demand that is price elastic indicates farm revenues will increase when price falls due to the greater quantity marketed. This is in contrast to most agricultural commodities which generally have demands that are price inelastic. This indicates that preventing or controlling off-flavor will increase the amount marketed and force a lower farm price, but that the price decrease will be more than compensated by the greater quantity marketed and total farm revenues will increase.

Using the value of -1.8 as the industry-wide farm level demand elasticity, further analysis calculated potential revenues if a technology to control or prevent off-flavor existed and allowed marketings to increase by 15 percent. Keeping in mind the limitations of the analysis, these potential revenues totaled some $8.3 million in 1985, with values per catfish operation in 1981 of $2,115. In addition, there may be distributional effects associated with these enhanced revenues, depending on the processor with whom a producer does business. These results support previous evidence that the catfish industry is currently in rather a unique situation for an agricultural commodity, that of having a price elastic demand at the farm level. As a result, anything that increases the amount marketed, not just preventing off-flavor, will enhance total farm revenue.

An important implication of an elastic demand for catfish regards the funding of research to solve the off-flavor problem. An argument often presented for funding agricultural research through tax dollars is that consumers are the primary beneficiaries of such research in the form of lower food prices. Because solving the off-flavor problem would raise the farm value of the catfish crop, producers, not consumers, may be the primary beneficiaries of a new off-flavor controlling technology. Thus, producers may wish to consider sharing in the cost of developing the needed technology. These research funds could be obtained, for example, by increasing the check-off on feed that currently exists to fund advertising, promotion and new product research. The estimates of producer benefits given could serve as a basis for determining the approximate amount of producer revenues to divert for the funding of research.

LIMITATIONS

The short-run revenue impacts of off-flavor developed in this study are based on an estimated industry-wide farm level demand elasticity of -1.8 and, moreover, on some general assumptions and additional restrictions imposed by the model and analysis. These general assumptions include: the quantity of live catfish marketed at any one time is less than possible because of off-flavor; preventing off-flavor will increase the quantity marketed in any one period; and that farm level demand can be modeled as described and estimated using disaggregated data from individual processing plants. The more technical assumptions regarding the estimate were presented in the section concerning the empirical analysis.

A key assumption used is that off-flavor restricts the amount of live catfish marketed. One may argue that since off-flavor does not permanently damage the product, these off-flavor fish are eventually sold and producers, rather than processors, are merely holding an inventory. According to the argument, unless these off-flavor fish are held over from one growing season to the next, off-flavor does not really affect the total amount marketed, only the timing of these marketings. It is important here to distinguish between quantity produced and available for marketing and actual quantity marketed. At any one time, the quantity marketed is probably less and certainly no more than the amount available for that purpose. The assumption in this study, (believed to be the case) is that in any given period, off-flavor reduces the amount actually marketed and preventing or controlling off-flavor will increase that amount. Whether this will also affect total production cannot be determined. It is emphasized that this report focuses on the short-run effects of off-flavor on total farm revenues, whereas a long-run analysis would consider the nature of the supply response.

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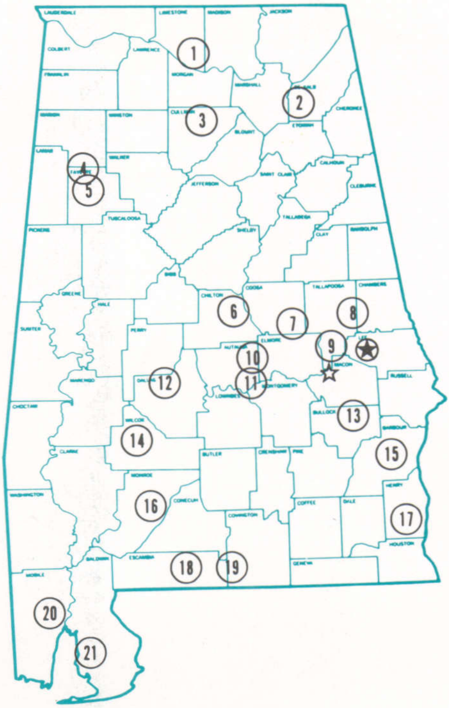

Research Unit Identification

⍟ Main Agricultural Experiment Station, Auburn.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Chilton Area Horticulture Substation, Clanton.
7. Forestry Unit, Coosa County.
8. Piedmont Substation, Camp Hill.
9. Plant Breeding Unit, Tallassee.
10. Forestry Unit, Autauga County.
11. Prattville Experiment Field, Prattville.
12. Black Belt Substation, Marion Junction.
13. The Turnipseed-Ikenberry Place, Union Springs.
14. Lower Coastal Plain Substation, Camden.
15. Forestry Unit, Barbour County.
16. Monroeville Experiment Field, Monroeville.
17. Wiregrass Substation, Headland.
18. Brewton Experiment Field, Brewton.
19. Solon Dixon Forestry Education Center, Covington and Escambia counties.
20. Ornamental Horticulture Substation, Spring Hill.
21. Gulf Coast Substation, Fairhope.