Economic Analysis of "Steam-Shock" and "Pasteurization" Processes for Oyster Shucking

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Introduction

"Steam-shock" is an oyster shucking process that uses steam to relax the oyster's adductor muscle, causing the oyster's shell to gap just enough to allow a shucking knife to be inserted without physical force. Inserting the knife without first prying the shells apart or breaking the bill of the shell saves the shucker's effort. Reducing effort and eliminating unnecessary motions translate directly into increased productivity. The increase in labor productivity has been estimated between 20 and 35 percent (Tanchoco and Coale, 1980). This paper presents an analysis of the costs and returns from the installation of the shucking process as in integral part of the operation of an existing oyster-shucking house.

The term "steam-shock" is used here instead of "steam-shucking" to avoid confusion with an older process that uses steam to cook the oyster meats, after which they are mechanically shaken out of their shells. Instead of cooking the meats, the steam-shock process exposes the oysters, still in their shells, to live steam only long enough to raise the temperature of the meat to about 120°F. This takes from 90 to 150 seconds, depending on the nature of the oysters and the temperature of the steam, and is achieved by carrying the shell stock through a steam tunnel, either on a flat conveyor belt or in a bucket hung from an overhead monorail. The conveyor belt method has been chosen for this analysis because it provides a more uniform exposure of the oysters to the steam than the monorail method. Steam-shocking produces a meat that is considered raw and is sold as such in the market.

The steam-shock process has a second advantage in that it can produce a reduction in the natural microflora present in the oyster when combined with rapid chilling of the meats (Wiley, 1980). This process also has the advantage that it can be used to produce a pasteurized product by heating the meats to about 140°F (Goldmintz et al., 1978). The pasteurization process in this paper is simply a variation of the steam-shock process in which the meats are heated to the higher temperature. This variation will be covered in the economic analysis.

The industrial trials with the steam-shock process were carried out by the J. W. Ferguson Seafood Company[1] in Remlick, Va., in 1977. Ferguson allowed knowledge of the process to spread and several other companies have adopted the process. Goldmintz et al. (1978) reported on the development of the pasteurized oyster product in 1978. The Virginia Polytechnic Institute and State University Sea Grant Advisory Service formed a multidisciplinary team to develop the new steam-shock technology in 1978. This led to a symposium in May 1980 and the publication of its proceedings (Huang and Hebard, 1980).

Principal Assumptions and Analysis of Benefits for the Steam-Shock Process

The analysis presented in this paper rests on the primary assumption that the factor limiting output for the oysterhouse is the number and productivity of its oyster shuckers. The increase in the shuckers' productivity due to the adoption of the steam-shock method is assumed to be 30 percent and is the primary benefit of the process (Tanchoco and Coale, 1980). This is within the range of the increase in oyster-shucking labor productivity commonly attributed to the adoption of the steam-shock process.

The analysis further assumes that the number and productivity of the shuckers continue to be the limiting factors in determining the output of the oysterhouse. The assumption of excess capacity in all factors other than shucking labor allows the production overhead costs to be fixed. Only those costs for items such as the number of cans that vary directly with the level of production and the cost of the steam tunnel then remain relevant to the decision regarding the installation of the steam tunnel. Because the oyster shuckers are normally paid on a piecework basis, it is not possible for the oysterhouse owner to directly recoup the costs of the steam-shock process from the increased labor productivity. Thus, it is necessary for the owners to recover their increased costs by spreading the fixed cost over a larger production. If the additional costs of installing and operating the steam process are less than the reduction in fixed costs, then the steam-shock process is taken to be a viable investment.

A second benefit from the steam-shock process is the potential for increasing the numbers of oyster shuckers. Because they are paid on a piecework basis, the higher productivity would result in increased earnings for the shuckers; this should then result in an increased labor supply for the industry. The process also lessens the skill required to shuck

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[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

oysters, because the need to force open the shells is no longer present. This allows new oyster shuckers to rapidly gain proficiency and to achieve full earning power quickly. The increase in labor supply will not be subject to analysis in this paper. The focus instead is on the cost savings from spreading the fixed costs over the larger production and the conditions necessary for the economic viability of the steam-shock product. In areas of labor shortages, however, the process may be adopted for labor reasons alone.

Two other benefits of the process are the savings that could result from the use of a cheaper grade of oysters for shucking and the potential for longer shelf life of the product. The steam-shock oysterhouses in Virginia occasionally use a grade of oysters called "snaps." The reason for the term and for the lower price is because the thinner shells will occasionally snap or break during the cold shucking process. Normally, shuckers will refuse to work with this grade of oyster, thus, it is obtainable at a discount on the market. The second source of savings could result from the potential for a longer shelf life for the oysters. Goldmintz et al. (1978) demonstrated this extended shelf life in their work on the pasteurized oyster. This possibility will be discussed later in this paper.

Cost Estimation

The costs of installing and operating the steam tunnel must be weighed against the benefits mentioned. The costs of purchasing and installing the necessary equipment are proportional to the processing capacity desired. The capacity of the steam tunnel is determined by its size, the temperature and volume of the steam, and the nature of the shell stock. A steam temperature of 180°-190°F and an exposure time of 90 seconds is recommended (Mashburn, 1980). Once the period of exposure to the steam has been fixed, the length of the tunnel determines the speed for the conveyor belt. The volume of shell stock the tunnel can handle in any period can be determined based on speed of the belt, width of the belt, and thickness of the shell stock covering the belt, as by the following equations:

Table 1.—U.S. bushel capacities.

Item	Capacity (cu. in.)	Item	Capacity (cu. in.)
U.S. Standard	2,150.4	Georgia	3,214.1
		Florida	3,214.1
Maryland	2,800.7	Alabama	2,826.2
Virginia	3,003.9	Mississippi	2,821.2
N. Carolina	2,801.9	Louisiana	2,148.4
S. Carolina	4,071.5	Texas	2,700.0

Speed × width × thickness = volume/time, or equivalently,

Length/time × width × thickness = volume/time.

For example, a tunnel 12 feet long and 24 inches wide with a covering 1-inch thick of oysters and a steaming time of 1.5 minutes has a capacity of 2,300 cubic inches/minute of shell stock or 64 U.S. standard bushels/hour.

The U.S. standard bushel is 2,150.4 cubic inches, which differs from most state bushels. The size of bushels used by the southeastern states is listed in Table 1. The sizes of these bushels vary by almost twofold, creating confusion in the market. In many instances the U.S. standard is already used in interstate trade, so that one must be sure of the volume of the bushel in local use.

The meat yield of the shell stock must be known to convert shell stock capacity to volume of meats per unit time. The meat yield varies substantially over the course of a year, depending upon the season and location, the size of oysters, and the nutritional quality and the salinity of the harvesting waters. Obviously, the meat yield will change the capacity of the steam tunnel. Diagrammed in Figures 1 and 2 are relationships between tunnel length, width, and meat yield in determination of the output of the tunnel.

The cost in this paper of installing the steam-shock process in an existing oysterhouse is based on the cost of the purchase and installation of a mesh-type conveyor, with an insulated aluminum box surrounding it, and pipe to carry the steam to the system. The oysterhouse is assumed to have enough space available for installation of the system.

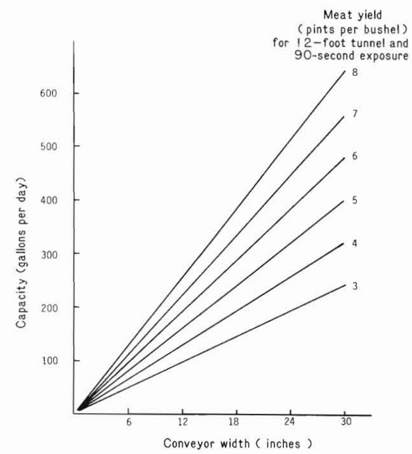

Figure 1.—Steam tunnel capacity vs. conveyor width.

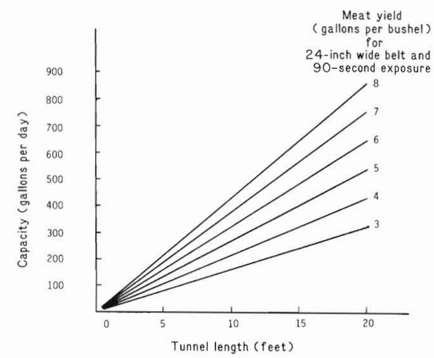

Figure 2.—Steam tunnel capacity vs. conveyor length.

The cost of the steam tunnel is a function of its size. The cost of the basic tunnel with a belt width of 24 inches and 12 feet long is estimated as $6,600, including installation. The cost per foot increase or decrease in length is estimated to be $200. The cost of a 30-inch belt width is estimated to be 112 percent of the cost of a 24-inch belt width, and the cost of an 18-inch width is estimated at 90 percent of the cost of the 24-inch belt width (Wiltse, 1979). Three standard lengths—8, 12, and 20 feet—were used, yielding a choice from nine tunnel sizes. If installation of a boiler sufficient to power the system is needed, the estimated additional cost is $8,000. Many oysterhouses, however, will already have sufficient boiler capacity. The capital costs are depreciated on a straight-line basis over an 8-year period with an interest rate of 18 percent. The length of the operating season is taken to be 150 working days, or about 30 weeks.

The results of calculations for assumed oysterhouse capacities from 50 to 400 gallons per day (GPD) are shown in Table 2. The range of output increases from 65 to 520 GPD when the 30 percent increase in productivity as a result of steam-shock processing is included. The third column shows the least expensive of the nine tunnel sizes capable of handling the output at a meat yield of 5 pints/U.S. standard bushel.

The assumed costs related to fuel consumption for each of the plant sizes are shown in Table 3. The second column shows the fixed tunnel costs per year including depreciation and interest costs for the tunnel purchase. The last two columns show the total costs per day of the steam-tunnel operation with and without the purchase of the boiler. The fact that the estimated costs do not increase as rapidly as the oysterhouse's physical capacity is important to note, because it introduces new economics of scale into the industry.

The results of this slower rate of cost increase can be seen in the economics of scale in Tables 4 and 5. The second column in both tables shows the new costs per additional gallon of oyster meats produced from the adoption of the steam-shock process. The cost per extra gallon drops from $2.59 to $0.49 as the size of the oysterhouse increases from 65 to 520 GPD for those houses that do not have to purchase a boiler. The decrease in cost for purchasing the boiler is from $3.46 for the 65 GPD operation to $0.60 for the 520 GPD operation.

The remaining three columns of Tables 4 and 5 contain the new average overhead per gallon for oysterhouses with a range of existing overheads from $1.50 to $2.50/gallon of meats. These overhead figures should include all costs that will not increase with the expected increase in output. Obvious exceptions would be the cost of shell stock, oyster shucker wages, and container costs, as these will change as the output increases. An examination of these two tables will show that the adoption of the steam tunnel is a viable investment for all sizes of oysterhouses except 65 GPD and at all cost structures except for the $1.50/gallon, 130 GPD oysterhouse when a boiler must be purchased. The larger the existing house, the more attractive the investment in the steam-shock process becomes because of the economics of scale. The reduction in overhead is 11.2 percent for the $2.50/gallon, 130 GPD oysterhouse, while it is 18.4 percent for the $2.50, 520 GPD oysterhouse, when neither need to purchase a boiler. The fact that both oysterhouses start with the same overhead, yet the larger one finishes with an $0.18/gallon cost advantage, is important, because it could forecast a tendency towards larger operations if this process becomes widespread.

Sensitivity Analysis

Since most of the values used in this paper are my estimates, based on informal exchanges with the industry and its suppliers, the sensitivity of the results to changes in the assumptions and estimates is examined. Varied estimates are conveyor cost, fuel cost and consumption, and the increase in oyster shuckers' productivity. The results are presented only for oysterhouses not needing to purchase a boiler.

When the cost of the steam tunnel is increased by 50 percent (Table 6), the cost per extra gallon of production now ranges from $2.88 for the 65 GPD oysterhouse to $0.50 for the 520 GPD oysterhouse. Because these are additional or marginal production costs, the adoption of the new technology will produce a lowering of costs if they are below the old average overhead costs. If they are above the old costs, then the adoption of the technology will increase costs. The extra costs are still below $1.50/gallon for all operations of 130 GPD and larger. The 50 percent increase in the tunnel

Table 2.—Original plant capacity, corresponding tunnel size, and capacity gains.

Original plant size (GPD)	New plant capacity (GPD)[1]	Steam-tunnel size[2]	Tunnel's full capacity (GPD)	Cost
50	65	18" × 8'	160	$5,400
100	130	18" × 8'	160	5,400
200	260	24" × 12'	321	6,600
300	390	30" × 12'	401	7,400
400	520	24" × 20'	535	8,400

[1]Assumes a 30 percent increase in output.
[2]At 5 pints/bushel and 1.5 minutes—least cost of the standard tunnel sizes (18, 24, 30 inches by 8, 12, 20 feet)

Table 3.—Tunnel costs for different sized plants.

New plant capacity (GPD)	Fuel consumption (gal/hour)	Tunnel costs fixed (per season)	Total costs (per 8-hour day)	Total costs with boiler purchase (per day)
65	2.5	$1,324	$38.82	$51.90
130	2.5	1,324	38.82	51.90
260	3.0	1,618	46.78	59.86
390	3.3	1,814	51.69	64.77
520	3.8	2,060	59.33	72.40

Table 4.—Costs per gallon of output without boiler purchase.

New plant cap (GPD)	Costs per addl gallon	New overhead cost per gallon when old overhead was:		
		$1.50/gal	$2.00/gal	$2.50/gal
65	$2.59	$1.75	$2.13	$2.52
130	1.29	1.45	1.84	2.22
260	0.78	1.33	1.72	2.10
390	0.57	1.28	1.67	2.06
520	0.49	1.27	1.65	2.04

Table 5.—Costs per gallon of output with the boiler purchase.

New plant cap	Costs per addl. gallon	New overhead cost per gallon when old overhead was:		
		$1.50/gal	$2.00/gal	$2.50/gal
65	$3.46	$1.95	$2.34	$2.72
130	1.73	1.55	1.93	2.32
260	1.00	1.38	1.77	2.15
390	0.72	1.32	1.70	2.09
520	0.60	1.29	1.68	2.06

Table 6.—Results of the sensitivity analysis.

New plant size	Marginal cost per gallon				
	Tunnel cost increased 50 percent	Fuel consumption increased 2 gallons/hour	Fuel cost $2.00/gallon	20% increase in shucker efficiency	Original assumptions
65	$2.88	$4.19	$3.25	$3.88	$2.59
130	1.44	2.09	1.63	1.94	1.29
260	0.86	1.18	0.97	1.16	0.78
390	0.64	0.91	0.72	0.86	0.57
520	0.55	0.61	0.62	0.74	0.49

cost produces an 11 percent increase in the cost per extra gallon in the 130 GPD oysterhouse, and a 10 percent increase for the largest oysterhouse.

The second estimate allowed to change is the fuel consumption. Two gallons per hour of fuel consumption were added for all sizes of tunnels. This amounts to an 80 percent increase for the 18-inch by 8-foot tunnel, and a 53 percent increase for the 24-inch by 20-foot tunnel. This increased the cost per extra gallon to $2.09 (a 62 percent increase) for the 130 GPD oysterhouse. The cost per extra gallon increased from $0.45 to $0.69 for the largest operation, a 53 percent increase. The third parameter altered is the fuel price. Using the original fuel consumption estimates and increasing the cost of fuel from $1.50/gallon to $2.00 increases the cost per extra gallon of meats from $1.29 to $1.63 for the 130 GPD oysterhouse. This is a 26 percent increase in costs. The cost per extra gallon of meats for the largest operation increases from $0.49 to $0.62, also a 26 percent increase.

The last variable altered is the increase in shucker efficiency. It was lowered from 30 to 20 percent, which is the lowest of the figures appearing in the literature (Tanchoco and Coale, 1980). This increased the marginal cost to $1.94 for the 130 GPD plant and to $0.68 for the 520 GPD oysterhouse. These are increases of 50 and 39 percent, respectively. The general results of the sensitivity analysis are that while the changes may make the steam-shock process unattractive to the low-cost 130 GPD oysterhouse, the marginal cost never rises above $1.18 for the operations over 260

Table 7.—Total cost per gallon estimates for three shucking processes.

Process	Shell-stock @ $/bu yield-ing 5 pints	Shuck-ing labor	Vari-able costs	Fixed costs	Total
Raw	$12.80	$3.59	$0.50	$2.00	$18.89
Steam-shock	12.80	3.59	0.50	1.72	18.61
Pasteur-ized	16.00	3.59	0.50	2.14	22.23

GPD in size and only rises above $2.00 for the 130 GPD oysterhouse for the high fuel consumption model.

The Pasteurized Product

The pasteurization of the steam-shock oyster requires the heating of the meats to a temperature of at least 140°F. This produces a second cost component, in addition to the costs of the steam tunnel, due to the loss of meat yield that occurs at the higher temperature. The meat yield as a percentage of the raw meat yield versus temperature from Goldmintz et al. (1978) is plotted in Figure 3. At 140°F the meat yield loss is about 20 percent from the raw product. The steam-shock process does not seem to produce a significant loss in meat yield (Huang, 1980). The calculations for the complete costs for the three systems—raw shuck, steam-shock (at 120°F), and pasteurization (at 140°F)—are shown in Table 7. The cost of inputs used are: 5 pints/standard bushel oysters at $8.00/bushel; shucking at $0.41/pound or $3.59/gallon; overhead at $2.00/gallon;

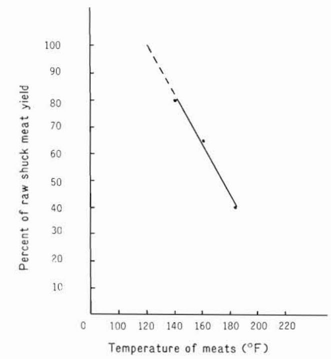

Figure 3.—Effect of temperature on meat yield (from Goldmintz et al. (1980)). Dashed part of line is linear extrapolation of Goldmintz et al. (1978) data made by Huang (1980).

and variable costs of $0.50/gallon. The size of the oysterhouse used for the comparison is 200 GPD, increased to 260 GPD for the steam-shock process, and 208 GPD for the pasteurized product (200 × 130 percent × 80 percent). The steam-shock process reduces the total cost per gallon to $18.61 from $18.89 for the raw shucked oysters. The pasteurized oysters cost $22.23/gallon to produce, an increase of $3.34/gallon above the raw product. This is due to the loss of meat yield.

There are several factors that could act to overcome the higher cost structure produced by the loss of yield in the pasteurization process. First, the lost liquor could be added back into the pack or sold as a byproduct for other uses. Second, there is evidence (Goldmintz[2]) that the pasteurized product could have a shelf life of 6 weeks or more (at 32°F) with the use of antioxidants to prevent oxidative rancidity. This longer shelf life would produce three benefits: 1) Lower distribution costs through less frequent deliveries; 2) a longer period to build stocks for the winter holiday season's period of peak demand; and 3) a greater willingness on the part of retailers to carry larger stocks of the product, thus increasing sales through a more constant availability. Another factor could be an increase in the numbers of consumers willing (and able) to purchase the pasteurized product, because they perceived it as "safer." Sanchez (1975) found a statistically significant (F-ratio = 41.69) difference in attitudinal means with respect to "safety compared with meats" of regular and irregular users of fresh shellfish.

Conclusions

The steam-shock process of oyster shucking has the potential for decreasing costs in the oyster industry through the spreading of fixed costs over a larger production for any individual oysterhouse. The second advantage of the process is the potential of increasing the number of shuckers available through higher wages for a less-skilled job.

The pasteurization process, while appearing to be a higher cost process, has the potential for producing a differentiated product. This product could be attractive to those who do not currently eat oysters. The higher costs might be covered by a premium price, a reduction in distribution costs, and the returning of the liquor to the pack.

The usefulness of the steam-shock process for oysters from southern waters remains untested, as all of the development work has been done with mid-Atlantic stocks. I am not aware of any work that has been done to determine their gapping reactions in the steam tunnel. Another area that remains relatively unexplored is the acceptability of the process for use with highly clustered intertidal oysters. Informal contacts with members of the industry who have performed private experiments with the clustered oysters indicate that the method does not work well on these oysters. The reason is said to be that the extreme range in size and position of the individual oysters within the cluster produces an unacceptable variance in the heating. The smallest oysters are cooked by the time the larger oysters gap their shells. Because of the potential drawbacks mentioned above, more controlled experimentation should be performed in order to verify the adaptability of the steam-shock process to other oyster stocks.

[2]Goldmintz, D., Charleston Laboratory, Southeast Fisheries Center, NMFS, NOAA, P.O. Box 12607, Charleston, SC 29412. Personal commun., March 1981.

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