# HACCP in Pork Processing: Costs and Benefits

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# Abstract

As public and private demand for food safety grows, firms need to be able to evaluate the optimal (least-cost) combinations of interventions to reduce pathogens. We use data from input suppliers to hog packing firms and from meat science studies to examine the cost function for pathogen reduction. An economic optimization model is used to explore the trade offs in achieving multiple pathogen reduction targets. Our data indicate costs of individual pathogen reduction technologies are in the range of \$0.03 to \$0.20 per carcass for hogs, and that optimal combinations of technologies may cost as much as \$0.47 per carcass.

The cost estimates for specific interventions show that power, water, and labor are important to achieve greater pathogen reductions. Thus operating costs for interventions are highly dependent on water and power rates. Labor costs (including training and turnover costs) are likely to become more important to holding down costs of monitoring and control. The cost issues surrounding food safety are linked to other performance issues in the meat industry.

Our estimated costs of pathogen reduction measures represent less than 2% of packing costs, although we caution that the total costs of HACCP must also include monitoring and testing costs. These estimates are considerably larger than initial FSIS estimates of HACCP costs to industry, but improvements in food safety may be achieved through relatively modest investments in large plants.

**Keywords:** HACCP, pork, processing costs

# HACCP IN PORK PROCESSING: COSTS AND BENEFITS

Food safety regulations issued in July 1996 mark a new approach to ensuring the safety of meat and poultry products. The U.S. Department of Agriculture's (USDA) Food Safety and Inspection Service (FSIS) moved from a system of carcass-by-carcass inspection to an approach that relies on science-based risk assessment and prevention through the use of Hazard Analysis and Critical Control Point (HACCP) systems (24, 25). Under the new regulations, the government requires meat processors to put a HACCP plan in place, to conduct periodic tests for microbial pathogens, and to reduce the incidence of pathogens. The new regulations shift greater responsibility for deciding *how* to improve food safety in the processing sector to processors themselves. Thus, the intent of this regulation was to promote more efficient resource allocation in food safety improvement (reducing inputs in control and/or improving food safety outcomes).

In addition to the need to improve the safety of food products to meet new federal standards, firms also have private incentives to improve both food safety and the shelf life of meat products. Currently, these private incentives are most apparent in growing export markets for meat products, but also occur through contracting of final product from large purchasers, such as ground beef for fast food restaurants (21). Thus, industry has both market and regulatory incentives to improve food safety, and to do so in the most cost-effective manner.

The demand for improved food safety has induced changes in methods used in meat processing for pathogen control. New technologies for pathogen control include both specific interventions or actions in the production process as well as new methods of managing process control (i.e., HACCP). The adoption of the new technologies allows the processing firm to achieve a safer food product through reduced pathogen levels. The challenge for the industry is to evaluate which set of interventions is the most cost-effective for achieving pathogen control.

In this paper, we investigate the production of food safety in meat processing in order to better understand the costs and benefits of changing food safety levels. The motivation for doing this is to provide better information for the marginal benefit/cost analysis of food safety interventions. This is the type of information that is needed to assess the cost-effectiveness of the new food safety regulation, as discussed in Unnevehr and Jensen and in MacDonald and Crutchfield (27). The FSIS impact assessment of the rule on food safety (24) was limited by lack of information on the marginal costs of food safety production.

Here, we specifically address: *a*) the structure of costs incurred by the firm in applying interventions to control food safety in meat processing; *b*) new data on the cost and effectiveness of selected food safety interventions in pork processing; and *c*) an economic framework for choosing optimal sets of interventions. The intent is to provide basic information on the cost frontier and, hence, marginal costs associated with improved pathogen control at the plant level.

The paper is organized as follows: in the next section we provide an overview of the HACCP based pathogen reduction regulation and previous estimates of the total cost of regulation. Next, we discuss the structure of costs and benefits for food safety improvement in pork processing. Then, we propose a model for evaluating adoption of selected technologies available to pork firms for pathogen control. The model results highlight the tradeoffs between private and public objectives for pork processing firms and reveal how steeply marginal costs rise as pathogen standards are tightened. In the final section we offer some implications with respect to the overall costs of achieving greater food safety.

## HACCP Regulation and Industry Costs of Improving Food Safety

Government intervention can take many forms, including direct regulation. How the regulation is specified has an effect on both the allocation decisions of the firm as well as the firm’s costs and profits under the regulation (11). The new FSIS rule regarding pathogen reduction combines both a process standard by requiring the adoption of a HACCP system and performance standard in setting allowable levels for *salmonella* and generic *E.coli* in products (27). According to Helfand (11), this type of combined standard theoretically encourages high levels of production but tends to reduce profits more than a simple performance standard.

In the case of microbial pathogens, performance standards are costly to monitor and enforce for many different pathogens. Thus, the combined performance/process standard represents an attempt to improve overall food safety without undue testing costs. Although there is no single indicator pathogen that can be used to evaluate the safety of products, testing for *salmonella* (by FSIS) on raw meat products is used to verify that standards for this microbial pathogen are being met; testing for generic *E.coli* (by the firms) on carcasses is used to verify the process control for fecal contamination (4). HACCP systems that reduce these two pathogen may be assumed to result in overall improvements in food safety.

The use of HACCP as the basis of pathogen control in plants has basically two components, as previous studies have recognized. The first component is the pure process control aspect of training, monitoring, record keeping, and testing, which has been the focus of previous estimates of the costs of the regulation to industry (19). The second component is the cost of specific interventions to reduce pathogens. Plants incur these costs in order to meet pathogen reduction goals; hence, these costs need to be considered as costs of the pathogen reduction regulation (15). Relatively little is known about the second set of costs, in part because there is uncertainty regarding how much new technology will be needed to meet specific pathogen reduction targets. Earlier forms of the FSIS regulation mandated that each firm would have to introduce at least one antimicrobial technique in the production process, but this requirement was abandoned in favor of allowing firms greater flexibility in meeting performance standards.

Roberts, Buzby and Ollinger (19) provide a summary of the costs for the meat and poultry industries estimated by the FSIS (both preliminary and revised) and by the Institute for Food Science and Engineering (IFSE) at Texas A&M. The annual costs of process control under HACCP consisted of planning and training, record keeping, and testing. The revised FSIS regulation cost estimates for these recurring process control efforts was $75 million; IFSE estimated these costs at $953 million. One source of the difference in the estimates was a very high estimate of testing costs from IFSE. They assumed that industry would have to incur costs over and above the required tests for *E.coli*, simply to monitor performance of their HACCP systems. The wide variation in estimated costs of implementing HACCP shows the inherent uncertainties and wide range of possible assumptions (e.g. the number of critical control points).

Regarding the second major component, process modification costs, FSIS reported an estimated range of $5.5 to 20 million (19). The modification cost estimates, however, are very uncertain because the extent of necessary modifications to meet performance standards is unknown. The original FSIS and the IFSE cost estimates did not include these costs explicitly. The later, revised, FSIS estimates include explicitly costs for out-of-compliance beef and pork plants to adopt steam vacuum systems and for poultry plants to adopt antimicrobial rinses (19). However, the steam vacuum technology is only one of several potential interventions in beef and pork (13).

Thus, none of the past cost estimates provides much information to support the choice of any particular performance standard based on marginal cost/benefit analysis. Furthermore, there is little available information to guide choices faced by meat processing firms in adopting different technologies for pathogen control. Therefore, we explore sources of new cost information below, but first we review the issues facing pork processing firms in evaluating pathogen reduction alternatives.

## Issues in Evaluating Costs and Benefits of Pathogen Reduction in Pork

Benefits of pathogen reduction or control include both private and public benefits. Crutchfield et al. (4) provide one estimate of public benefits that includes cost of illness, lost productivity, and loss of life. They estimate that food borne illnesses attributed to meat and poultry alone from six microbial pathogens cost the U.S. economy $2.0 to $6.7 billion annually for 1995. Table 1 compares their total food borne cost of illness estimates for selected pathogens with the prevalence of the same pathogens on pork carcasses in the 1995-96 USDA Microbiological Baseline. Although prevalence for most individual pathogens is low, pork is a potential source of four economically important pathogens: *staphyloccocus aureus, clostridium perfringens, campylobacter jejuni/coli,* and *salmonella*. It should be noted that traceback to individual food sources is difficult. Nevertheless, there are potential public benefits from reductions in pathogen incidence on pork carcasses, which could presumably reduce pathogen prevalence later in the food chain.

Private benefits from pathogen reduction include improvements in shelf life, access to new markets such as export markets, retention of customers, decreased scrap or reworking of product, and reduced product liability. These benefits are clear to many pork processing firms, but it is difficult to assign a specific dollar value to any of them. Access to export markets may be an

**Table 1: Prevalence of Selected Microorganisms on Pork Carcasses and Their Costs of Food Borne Illness from Meat and Poultry Alone**

| Microorganism | Percent of samples positive on pork carcasses | Costs of food borne illness (low estimates) (billion $) |
|---|---|---|
| Total Coliforms | 45.4 | NA |
| E. coli (biotype I) | 31.0 | NA |
| Clostridium perfringens | 10.4 | 0.1-0.3 |
| Staphyloccocus aureus | 16.0 | 0.6-1.7 |
| Listeria monocytogenes | 7.4 | 0.1-0.7 |
| Campylobacter jejuni/coli | 31.5 | 0.5-0.9 |
| E. coli O157:H7 | 0 | 0.2-0.7 |
| Salmonella | 8.7 | 0.5-2.4 |

Sources: USDA/FSIS Microbiological Baseline Data Collection (26), Apr 1995- Mar 1996; and USDA Economic Research Service (14).

important motivation. Shipping to those markets in Asia requires both extended shelf life and assuring buyers of the highest possible level of food safety.

We turn now to consideration of firm level issues in controlling food borne pathogens. The major stages of the production process for pork include: incoming animals; pre-evisceration; post-evisceration; chilling; fabrication; and packing. Each stage can have monitored CCP's and/or some microbial control interventions. If firms want to reduce pathogens on pork carcasses they must consider two issues: a) how to control multiple pathogen targets; and b) where in the process to intervene.

Microbial pathogen control in the slaughter and processing environment involves control of hazards of various types. Some hazards are brought into the plant with the animals (many pathogens such as *salmonella* live in the enteric systems of animals); other hazards contaminate product through worker or other environmental contamination (such as *staphyloccocus aureus* or *listeria*). Some hazards grow (multiply) on product; others do not multiply. Thus specific HACCP controls may or may not control more than one pathogen. For example, a recent plant study by Saide-Albornoz et al. (20) found prevalence levels for four pathogens, including *Salmonella spp*., declined as carcasses passed through processing stages from singeing to chilling, but prevalence of *S. aureus* increased. *S. aureus* is usually carried by humans and the increased levels observed at later stages of processing were probably due to the increased human handling.

We have focused below on control of pathogens from the enteric systems of animals, which is the current focus of regulatory activity. In this case, methods applied to control of one pathogen often affect or control other pathogens as well, but perhaps not to the same degree. Generic *E. coli* is associated with fecal contamination of product, and its presence is likely to be an indicator of other associated contamination (or the potential for contamination), e.g. from salmonella. Total aerobic bacteria affects shelf life, and may be controlled by similar interventions. Thus certain kinds of safety and quality can be jointly produced through particular production processes (e.g., chilling carcasses or acid rinses).

The HACCP framework provides guidance on the issue of where to intervene in the process. During slaughter, evisceration, and chilling carcasses, the process provides opportunity for carcass contamination and cross-contamination. Presence or growth of pathogens can be affected by temperature, environment (e.g., acidity), physical pressures (e.g., washing), and time of year or day during which processing occurs. Thus, a HACCP system recognizes the need for control and monitoring throughout the production process and helps plants identify where to intervene. Pathogen reduction efforts at different intervention points, often at Critical Control Points (CCPs), affect the level of pathogens at that point in the process, but they can also reduce subsequent hazards. A simple example would be whether a hot water carcass rinse is applied before or after evisceration, or at both times.

Pork processing firms may adopt HACCP systems which monitor and verify the control from existing procedures inherent to the process of slaughter, evisceration, chilling, and fabrication. Examples of such procedures include scalding, singeing, chilling, or knife rinsing between carcasses. Presumably HACCP would make these procedures more effective through increased employee awareness and reduced variability in implementation. But firms may also find that existing procedures do not accomplish desired pathogen reductions. Thus, as private and public demand for food safety grows, firms may seek additional interventions focused on pathogen reduction. During the rest of the paper, we consider the cost-effectiveness of such interventions in pork processing.

## Cost-Effectiveness of Different Technologies for Pathogen Control in Pork

In the past few years, several new and existing technologies have been more widely adopted and adapted for pathogen reduction in the pork packing industry. Interventions available for pork include carcass wash, sanitizing sprays, steam vacuum, and carcass (hot water) pasteurizer. The carcass wash is a cabinet that provides a hot water rinse to the carcass, and has been in use for over 25 years. Washes can be applied either pre- or post-evisceration, and can be applied at different temperatures, with different pressures, and, for sanitizing sprays, at different levels of acidity. Sanitizing sprays, usually acetic acid, are most often used post-evisceration, in combination with hot water rinses. These sprays are a relatively new control technology, that has only been adopted during the last 5 to 10 years. Steam vacuums, also relatively new, are used to remove contamination from specific parts of the carcass, and may be utilized at different points in the process. Hot water pasteurizers have been developed in Canada for hog carcasses, but have not yet been adopted in the United States. The adoption of a new technology in processing must be approved by FSIS before its use.

Costs of technologies used to increase food safety in product include both fixed (equipment) and variable costs. Data regarding costs of equipment and inputs required for operation were obtained directly from input suppliers of new technologies.[1] Comparable operating and depreciation costs were constructed for all technologies with representative prices for energy, water, labor, and capital. These cost estimates are representative of large plants, i.e. pork packing plants processing 800–1200 carcasses per hour, which account for over 85% of total pork supply. Fixed costs are highest for the newest technology, pasteurizers, and much lower for other interventions (Table 2). Energy and water are the principal components of variable costs. Variable costs are also highest for pasteurizers, due to their high energy costs. Total costs per carcass are thus highest for carcass pasteurizers, followed by sanitizing spray systems, steam vacuum, and hog carcass wash. Total costs range from 5 cents per carcass for washes at 55 degrees C to nearly 16 cents per carcass for hot water pasteurizers, and can be up to 20 cents for high temperature washes of 65 degrees C. The newer technologies have higher total costs than the older technology of low temperature carcass washing.

**Table 2. Fixed, Variable, and Total Costs ($/Carcass) of Different Technologies: Pork**

| | Hog Carcass Wash[a] | Sanitizing Spray System[a] | Carcass Pasteurizer[b] | Steam Vacuum[c] |
|---|---|---|---|---|
| Fixed Costs | | | | |
| Nominal cost equipment | 10,900 | 32,900 | 200,000 | 12,500 |
| Installation | 12,000 | | | |
| Freight | 7,000 | 7,000 | | |
| Spare parts | 2,281 | | | |
| Total | 32,181 | 39,900 | 200,000 | 12,500 |
| Medium term fixed costs per carcass[d] | 0.00655 | 0.00812 | 0.04069 | 0.00254 |
| Variable Costs | | | | |
| Water | 0.00140 | 0.00008 | 0.00021 | 0.00003 |
| Electric | 0.00052 | 0.00557 | 0.00174 | 0.00063 |
| Effluent | 0.00141 | 0.00008 | 0.00021 | 0.00024 |
| Natural gas | 0.04201 | 0.08402 | 0.11004 | 0.00000 |
| Labor | 0.00271 | 0.00271 | 0.00271 | 0.01300 |
| Solution | NA | 0.00500 | NA | NA |
| Total variable cost ($/carcass)[d] | 0.04804 | 0.09746 | 0.11491 | 0.01390 |
| Total Costs | | | | |
| Total costs per carcass | 0.05459 | 0.10557 | 0.15559 | 0.08220 |

[a] *Sources:* Chad Company (3) and Birko Company (1). These costs are for a 55 degree C rinse. Costs for a 25 degree C and a 65 degree C rinse would be .02659 and .08260 cents per carcass, respectively. [b] Stanfos, Inc.(23). [c] Jarvis Company(12); Total cost based on use of 5 vacuums.
[d] Based on plant processing 1200 carcasses per hour, 16 hours a day, 260 days a year. Medium term fixed costs use a 10-year depreciation period and a 10% annual interest rate.

Interventions are often used in combination for pathogen control, and such combinations can result in pathogen reduction that is non-additive. Thus, evaluation of alternative interventions would ideally include evaluation of combinations of interventions or use of interventions at different points in the process. However, those types of studies are unusual, and furthermore, the literature on pathogen reduction technologies for pork is much smaller than that for beef (22).

Data regarding pathogen reductions are drawn from two published studies by meat scientists.[2] Dickson (5) reports reductions in total aerobic bacteria and total enterics for water rinses at different temperatures and with or without sanitizing sprays; data regarding the carcass pasteurizer are available from Gill, Bedard, and Jones (9) (Table 3). In the Dickson (5) study, carcasses were innoculated with relatively high levels of pathogens, whereas they were not in the Gill, Bedard, and Jones (9) study. The Dickson (5) study shows that higher reductions occur as water temperature increases and as rinses are combined with sanitizing sprays, and that reductions are generally to one-half of the initial levels. The Gill, Bedard, and Jones (9) study shows that the carcass pasteurizer virtually eliminates the lower levels observed during processing.[3]

**Table 3. Mean Pathogen Reduction of Different Technologies in Hog Carcasses($\log_{10}$ Counts)**

| Type of Microorganism | (7) Carcass Pasteur.[a] | (1) Water Rinse (25C)[b] | (2) Water Rinse (25C) and Sanit. Sp.[b] | (3) Water Rinse (55C)[b] | (4) Water rinse (55C) and Sanit. Sp.[b] | (5) Water rinse (65C)[b] | (6) Water rinse (65C)[b] and Sanit. Sp. [b] |
|---|---|---|---|---|---|---|---|
| ***Total Aerobic Bacteria (TAB)*** | | | | | | | |
| Before treatment | 2.38 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| After treatment | 0.39 | 3.49 | 2.25 | 2.64 | 2.25 | 2.06 | 1.76 |
| % reduction in log measure | 83.61 | 22.44 | 50.00 | 41.33 | 50.00 | 54.22 | 60.89 |
| ***Total Enterics (TE)*** | | | | | | | |
| After treatment | 0.0 | 2.71 | 1.13 | 1.41 | 1.48 | 1.68 | 0.0 |
| % reduction in log measure | 100.00 | 34.15 | 72.44 | 65.61 | 63.90 | 59.02 | 100.00 |
| ***Cost*** | | | | | | | |
| 1200 carc./h ($/Carcass) | 0.15559 | 0.02659 | 0.14057 | 0.05459 | 0.16857 | 0.08260 | 0.19658 |

[a] *Source:* Gill, C. O., D. Bedard, and T. Jones (9). The samples were taken from parts other than the anal area of the carcass. The samples were taken during the plant operation, and were not contaminated intentionally.

[b] *Source:* Dickson (5). In this experiment the carcasses were intentionally contaminated.

Table 3 also shows that costs increase as more energy is used to heat water (3 to 8 cents per carcass) and as sanitizing sprays are added (14 to 20 cents per carcass). Greater pathogen reductions in pork are associated with higher costs. The use of the sanitizing spray with the highest water temperature (6) provides the greatest pathogen reduction at more than double the cost over the use of highest temperature water rinses alone.[4]

## A Model for Minimizing the Costs of Pathogen Reduction

Firms can use one or more interventions to reduce pathogen levels on carcasses at the end of the kill floor process. Interventions may result in different levels of reduction for different pathogens. We assume that each intervention reduces pathogen levels by some percentage amount from the initial level on the carcass. The economic problem is to choose the most cost-effective set of interventions to meet a set of pathogen standards. This can be formulated as:

$$\underset{X_i}{Min} \sum_{i=1}^{N} C_i X_i$$

s.t.

$$I_j * \prod_{i=j}^{N} \left(1 - P_{ij} X_i\right) \le S_j \quad j = 1, 2, \ldots, j \quad \text{(nonlinear constraints)}$$

$$X_i \text{: binary variable, } \forall \mathrm{X_i};\ i = 1, 2, \ldots, N$$

where

N: Number of activities

J: Number of pathogen varieties to monitor by HACCP

Xi: Activity i, binary variable.

Ci: cost of activity i

Pij: percentage of pathogen j reduced by performing activity i.

Sj: maximum number of pathogen j allowed by regulation.

Ij: Initial level of pathogen j.

This model chooses the least cost set of N possible interventions to achieve standards, Sj, for j pathogens, given the initial levels of pathogens (Ij), the effectiveness of interventions (Pij), and their costs (Ci). In this formulation, the order of the interventions does not matter (as it might in practice). Each intervention can only be used once, which accords with how interventions have been adopted by stages in plants.

This model was implemented for the set of rinse and spray interventions at different temperatures from Table 3. Table 4 reports the optimal costs and sets of interventions for initial pathogen levels equal to those in the Dickson (5) study. The model chooses 10 different optimal combinations of activities as pathogen standards are tightened, with corresponding costs increasing from 3 to 47 cents per carcass. For example, reduction of aerobic bacteria to 1.25 CFU and of enterics to 0.75 CFU requires use of two hot water rinses at 55 and 65 degrees C, at a cost of 13.7 cents per carcass. Costs increase steeply as desired pathogen levels approach zero. For aerobic bacteria counts of 0.25 CFU and no detectable enterics, costs are 47 cents per carcass, and four different interventions are used. Sanitizing sprays enter the optimal set of interventions only in the last four combinations for standards lower than 0.75 and 0.25 CFU respectively for TAB and TE. It is interesting that among the least cost combinations of technologies selectd, the one that was required for the greatest relative pathogen control is comparable to the recommended complete set of equipment sold by Chad Co. (3).

Figure 1 shows the three dimensional cost surface, which combines the step cost functions for reduction of TAB and TE. The figure demonstrates that costs rise more steeply for near elimination of TAB than for TE. Thus, these data show that costs are higher for improving shelf life than they are for improving food safety.

**Table 4: Least Cost Combinations of Washes and Sanitizing Sprays to Achieve Different Pathogen Standards**

| Pathogen Standard | | Cost | Activity | | | | Final Level | |
|---|---|---|---|---|---|---|---|---|
| **TAB** | **TE** | | | | | | **TAB** | **TE** |
| 4.50 | 4.25 | 0 | 0 | 0 | 0 | 0 | 4.50 | 4.10 |
| 3.50 | 2.75 | 0.0266 | 0 | 0 | 0 | 1 | 3.49 | 2.70 |
| 2.75 | 1.50 | 0.0546 | 0 | 0 | 0 | 3 | 2.64 | 1.41 |
| 2.25 | 1.00 | 0.0812 | 0 | 0 | 1 | 3 | 2.05 | 0.93 |
| 1.75 | 1.25 | 0.1092 | 0 | 0 | 1 | 5 | 1.60 | 1.11 |
| 1.25 | 0.75 | 0.1372 | 0 | 0 | 3 | 5 | 1.21 | 0.58 |
| 1.00 | 0.50 | 0.1638 | 0 | 1 | 3 | 5 | 0.94 | 0.38 |
| 0.75 | 0.25 | 0.2778 | 0 | 2 | 3 | 5 | 0.60 | 0.16 |
| 0.50 | 0.25 | 0.3043 | 1 | 2 | 3 | 5 | 0.47 | 0.10 |
| 0.50 | 0.00 | 0.3338 | 0 | 3 | 5 | 6 | 0.47 | 0.00 |
| 0.25 | 0.00 | 0.4743 | 2 | 3 | 5 | 6 | 0.24 | 0.00 |

Note: Initial level of TAB is 4.5 and TE is 4.1.

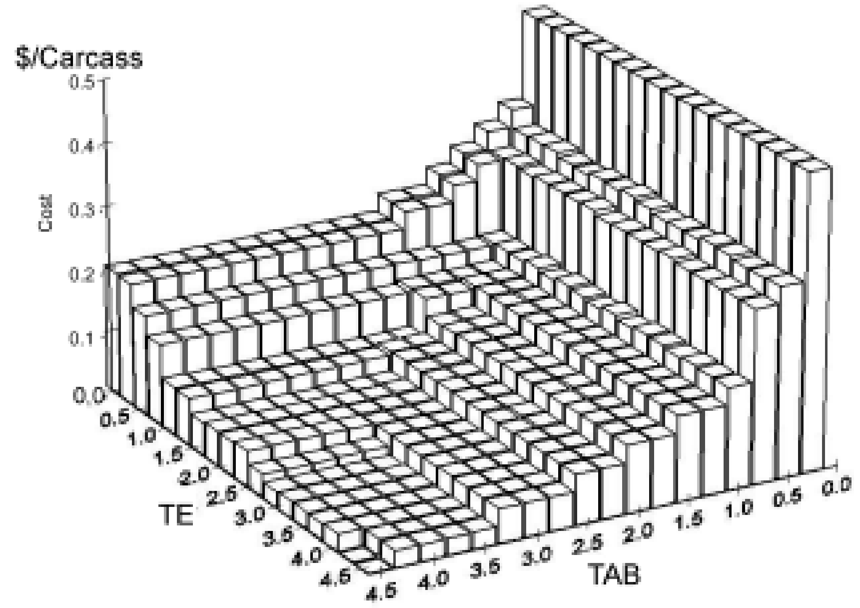

Figure 1. Optimal costs for different pathogen standards (combinations of carcass wash and sanitizing sprays.

We also performed a preliminary analysis of the hot water carcass pasteurizer. Although the data in Table 3 are not directly comparable to those for hot water rinses and sprays, it seemed useful to explore conditions under which the pasteurizer might be adopted. The pasteurizer reduces the costs of achieving very low levels of pathogens (Table 5 and Figure 2). For TAB levels of 0.25 CFU and non-detectable TE, the cost is 29 cents per carcass. This is achieved through combining rinses at 55 and 65 degrees C with the hot water pasteurizer. Figure 3 shows the reduction in the upper levels of the cost surface, particularly for TAB. Thus, the carcass pasteurizer may be adopted as the desirable level of control increases.

Our model also allows exploration of the value of reducing initial levels of pathogens. This might be achieved through investments in HACCP earlier in the slaughter process or through control of pathogens in animals entering the plant. As veterinarians are currently exploring the feasibility of delivering pigs for processing with reduced pathogen contamination, it is useful to explore the potential value for the plant of controlling incoming animal status.

**Table 5: Least Cost Combinations of Washes, Sanitizing Sprays, and Hot Water Pasteurizer to Achieve Different Pathogen Standards**

| Pathogen Standard | | Cost | Activity | | | | Final Level | |
|---|---|---|---|---|---|---|---|---|
| **TAB** | **TE** | | | | | | **TAB** | **TE** |
| 4.50 | 4.25 | 0 | 0 | 0 | 0 | 0 | 4.50 | 4.10 |
| 3.50 | 2.75 | 0.0266 | 0 | 0 | 0 | 1 | 3.49 | 2.70 |
| 2.75 | 1.50 | 0.0546 | 0 | 0 | 0 | 3 | 2.64 | 1.41 |
| 2.25 | 1.00 | 0.0812 | 0 | 0 | 1 | 3 | 2.05 | 0.93 |
| 1.75 | 1.25 | 0.1092 | 0 | 0 | 1 | 5 | 1.60 | 1.11 |
| 1.25 | 0.75 | 0.1372 | 0 | 0 | 3 | 5 | 1.21 | 0.58 |
| 0.75 | 0.00 | 0.1556 | 0 | 0 | 0 | 7 | 0.74 | 0.00 |
| 0.50 | 0.00 | 0.2102 | 0 | 0 | 3 | 7 | 0.43 | 0.00 |
| 0.25 | 0.00 | 0.2928 | 0 | 3 | 5 | 7 | 0.20 | 0.00 |

Note: Initial level of TAB is 4.5 and TE is 4.1.Table 6 shows how the costs vary with initial pathogen levels and desired pathogen standards. Although many of these initial levels are significantly above expected levels, the data

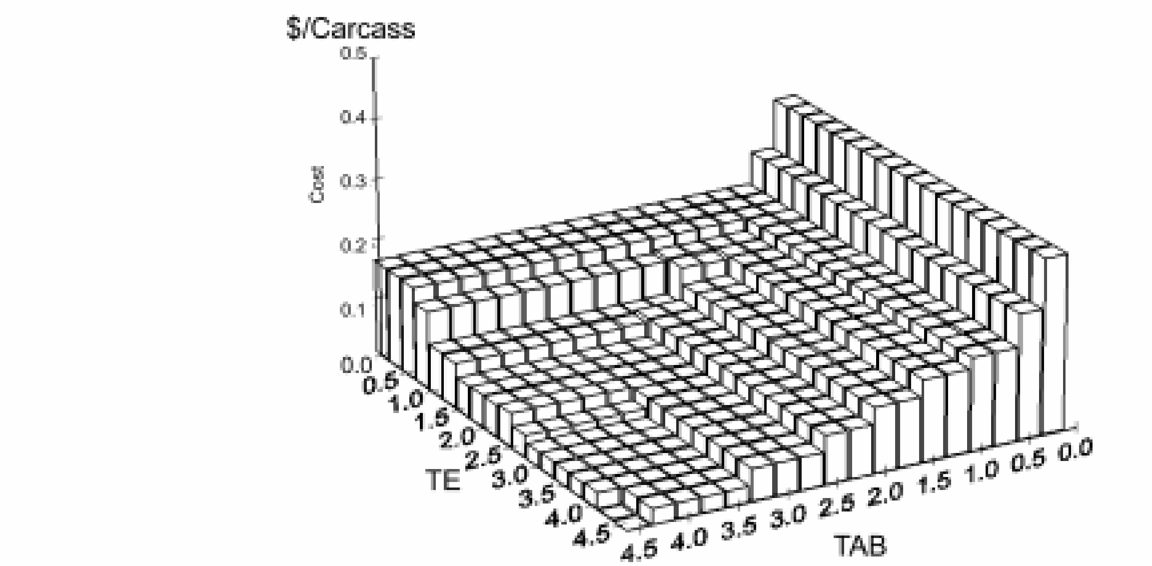

Figure 2. Optimal costs for different pathogen standards (combinations of carcass wash and sanitizing sprays, and hot water pasteurizer).

**Table 6: Least Cost Combinations of Pathogen Reduction Technologies with Different Initial Levels and Standards**

| Pathogen Standard | | Initial Level | | | | | |
|---|---|---|---|---|---|---|---|
| S(J) | | IL(J) | | Cost | Technologies | Final Level | |
| **TAB** | **TE** | **TAB** | **TE** | | | **TAB** | **TE** |
| 0.50 | 0.75 | 2.50 | 2.00 | 0.2498 | 1,2,5 | 0.44 | 0.15 |
| 0.50 | 0.75 | 3.00 | 2.50 | 0.2778 | 2,3,5 | 0.4 | 0.1 |
| 0.50 | 0.75 | 3.50 | 3.00 | 0.2778 | 2,3,5 | 0.47 | 0.12 |
| 0.50 | 0.75 | 4.00 | 3.50 | 0.3043 | 1,3,5,2 | 0.42 | 0.09 |
| 0.50 | 0.75 | 4.50 | 4.10 | 0.3043 | 1,3,5,2 | 0.42 | 0.09 |
| 0.75 | 0.75 | 2.50 | 2.00 | 0.1372 | 1,5 | 0.67 | 0.28 |
| 0.75 | 0.75 | 3.00 | 2.50 | 0.1638 | 1,3,5 | 0.62 | 0.23 |
| 0.75 | 0.75 | 3.50 | 3.00 | 0.1638 | 1,3,5 | 0.73 | 0.28 |
| 0.75 | 0.75 | 4.00 | 3.50 | 0.2498 | 1,2,5 | 0.71 | 0.26 |
| 0.75 | 0.75 | 4.50 | 4.10 | 0.2778 | 2,3,5 | 0.60 | 0.16 |
| 0.75 | 1.00 | 2.50 | 2.00 | 0.1372 | 3,5 | 0.67 | 0.28 |
| 0.75 | 1.00 | 3.00 | 2.50 | 0.1638 | 1,3,5 | 0.62 | 0.23 |
| 0.75 | 1.00 | 3.50 | 3.00 | 0.1638 | 1,3,5 | 0.73 | 0.28 |
| 0.75 | 1.00 | 4.00 | 3.50 | 0.2498 | 1,2,5 | 0.71 | 0.26 |
| 0.75 | 1.00 | 4.50 | 4.10 | 0.2778 | 2,3,5 | 0.60 | 0.16 |
| 1.00 | 1.00 | 2.50 | 2.00 | 0.1092 | 1,5 | 0.89 | 0.54 |
| 1.00 | 1.00 | 3.00 | 2.50 | 0.1372 | 3,5 | 0.81 | 0.35 |
| 1.00 | 1.00 | 3.50 | 3.00 | 0.1372 | 3,5 | 0.94 | 0.42 |
| 1.00 | 1.00 | 4.00 | 3.50 | 0.1638 | 1,3,5 | 0.83 | 0.32 |
| 1.00 | 1.00 | 4.50 | 4.10 | 0.1638 | 1,3,5 | 0.83 | 0.32 |

show that within the range observed with these experimental data, reduction of initial pathogen levels can reduce costs of pathogen reduction by 5 to 14 cents per carcass, depending upon the desired pathogen standard. Basically, controlling initial levels of pathogens would reduce the required post-evisceration controls. However, this would lead to only relatively small premiums for live hogs from farms controlling pathogens.

## Comparison with Overall Processing and HACCP Costs

Costs of intervention per carcass are small in comparison to total costs of processing in large plants. For pork, Melton and Huffman (17) estimate the value-added packing costs to be $.10 per pound for 1988; in current dollars, this would be $30 per carcass. In comparison, Hayenga (10) estimates that large hog packing plants today have variable costs of $22 per carcass, and fixed costs of $6 per carcass, for a single shift, large plant. He estimates total costs to be $28 for a single shift and $23 for a double shift operation.

The additional costs of 20 cents for hot water rinses and sanitizing sprays represent an increase of less than 1% (0.7-0.9%). Our highest cost optimal combination for pathogen reduction would be 47 cents, which would be only 1 to 2% of total processing costs. Thus, these new technologies for large plants represent a relatively small potential increase relative to other determinants of cost variation in the industry, such as scale or number of shifts. In a competitive industry, however, achieving efficiency in meeting the new regulation represents a significant challenge to firms.

Our overall estimate of HACCP costs is somewhat higher than the final FSIS cost estimates of $0.00003/lb. (or $.0056 per carcass) for large hog firms (4). These costs represent all of the costs of implementing HACCP, of which process modifications were only assumed to be a small part. FSIS assumed that half of pork and beef plants would adopt steam vacuums to achieve additional pathogen reductions, and that these would cost about $.08 per carcass (similar to our estimates in Table 2). FSIS did not consider the costs of any other potential interventions. Thus, if more plants adopt the other technologies considered above (or if our preliminary estimates of HACCP implementation are robust), the costs of pathogen reduction could be higher.

Current premiums for quality through carcass value pricing cause variations of plus/minus $5 per carcass (14). Thus incentives for improving food safety to hog producers are likely to be very small relative compared to incentives for delivering high quality animals with desired weight and backfat. While our data are only preliminary, they point to the relatively small costs of post-evisceration control.

Another technology for reducing risk of food borne illness from meats is irradiation. The federal government is currently evaluating changes in regulation to allow its use for red meat.

Irradiation cost estimates for ground beef product are between 2 and 5 cents per pound (16). Comparable costs would be expected for pork products of similar nature (e.g., thickness). Hence, irradiation offers an alternative technology, although a relatively high cost one. It is likely that given the relative costs, when used, it would be in combination with other technologies.

We caution that these results are preliminary in several senses—more studies of pathogen reduction under plant conditions are needed; new technologies are emerging to control pathogens; and they represent only part of the costs of a full HACCP system that includes monitoring and verification. Some interventions or combinations of interventions appear to dominate and will be more cost-effective. But, their effectiveness in real world situations is still unclear. Plants may obtain their own information about cost-effectiveness based on internal review; however, that information is only available post-adoption. Therefore, much experimentation will be necessary; industry should evaluate new options carefully and may want to foster more public research to compare and fine-tune technologies.

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# References

Birko Company. 1997. Personal communication with Gene Chase, company representative, Henderson CO, November.

Buzby, J.C., T.Roberts, C.-T. Jordan Lin, and J.M. MacDonald. August 1996. “Bacterial Foodborne Disease: Medical Costs and Productivity Losses.” Economic Research Service, United States Department of Agriculture, *Agricultural Economic Report* No. 741.

CHAD Company. September 1997. Personal communication with Mike Gangel, President, Lexena KS.

Crutchfield, S. R., J. C.Buzby, T. Roberts, M. Ollinger, and C.-T. J. Lin. July 1997. “An Economic Assessment of Food Safety Regulations: The New Approach to Meat and Poultry Inspection.” Economic Research Service, United States Department of Agriculture, *Agricultural Economic Report* No. 755.

Dickson, J. S. October 1997. “Hot Water Rinses as a Bacteriological Intervention Strategy on Swine Carcasses.” Proceedings of The Food Safety Consortium Annual Meeting, Kansas City, MO.

Epling, L.K., J.A. Carpenter, and L.C. Blankenship. 1993. “Prevalence of Campybacter spp. And Salmonella spp. on Pork Carcasses and the Reduction Effected by Spraying with Lactic Acid.” *J. Food Prot.*, Vol 56 (6):536-537.

Frederick, T.L., M.F. Miller, L.D. Thompson, and C.B. Ramsey. 1994. “Microbiological Properties of Pork Cheek Meat as Affected by Acetic Acid and Temperature.” *J. Food Sci.*, vol 59(2):300-302.

Fu, A.-H., J.G. Sebranek, and E.A. Murano. 1994. “Microbial and Quality Characteristics of Pork Cuts from Carcasses Treated with Sanitizing Sprays.” *J. Food Sci.*, Vol 59(2):306-309.

Gill, C. O., D. Bedard, and T. Jones. 1997. “The Decontaminating Performance of a Commercial Apparatus for Pasteurizing Polished Pig Carcasses”. *Food Micro.* 14:71-79.

Hayenga, Marvin L. November 13, 1997. “Cost Structures of Pork Slaughter and Processing Firms: Behavioral and Performance Implications.” Department of Economics, Iowa State University Staff Paper No. 287. Ames, IA: Iowa State University.

Helfand, Gloria E. June 1991. “Standards Versus Standards: The Effects of Different Pollution Restrictions.” *Am. Ec. Rev.* 81:622-34.

Jarvis Company. October 1997. Personal communication with Tommy Fulgham, Manager, Meat Machinery Division, Middletown CT.

Jensen, H.H., L.J. Unnevehr, and M.I. Gomez. Spring 1998. “Costs of Improving Food Safety in the Meat Sector.” *J. Ag. and Ap. Ec.*, Vol. 20, No. 1, in press.

Lee, Kyu-Hee. 1995. “Evaluation of Packers’ Pricing Mechanisms in the Hog Industry: A Simulation Approach.” Master’s thesis, Department of Agricultural Economics, University of Illinois at Urbana-Champaign.

MacDonald, James M. and Stephen Crutchfield. December 1996. “Modeling the Costs of Food Safety Regulation.” *Am. J. Ag. Ec.* 78:1285-90.

McCafferty, Dennis. January 23-25, 1998. “Get ready for irradiated meat.” *USA Weekend*. (http://www.usaweekend.com/98_issues/980125/980125irradiated_meat.html).

Melton, Bryan E. and Wallace E. Huffman. August 1995. “Beef and Pork Packing Costs and Input Demands: Effects of Unionization and Technology.” *Am. J. Ag. Ec.* 77:471-85.

Morrison, Rosanna Mentzer; Jean C. Buzby, and C.-T. Jordan Lin. Jan.-April 1997. “Irradiating Ground Beef to Enhance Food Safety.” *Food Rev.*, 33-37.

Roberts, Tanya, Jean C. Buzby, and Michael Ollinger. December 1996. “Using Benefit and Cost Information to Evaluate a Food Safety Regulation: HACCP for Meat and Poultry.” *Am. J. Ag. Ec.* 78:1297-1301.

Saide-Albornoz, Jaime J., C. Lynn Knipe, Elsa A. Murano, and George W. Beran. September 1995. "Contamination of Pork Carcasses during Slaughter, Fabrication, and Chilled Storage." *J. Food Prot.* 58:993-997.

Seward, Skip. December 1995. “Integrating Data for Risk Management: Comments.” in *Tracking Foodborne Pathogens from Farm to Table: Data Needs to Evaluate Control Options*, ed. Roberts et al, USDA Economic Research Service Miscellaneous Publication No. 1532.

Siragusa, G.R. 1995. “The Effectiveness of Carcass Decontamination Systems for Controlling the Presence of Pathogens on the Surfaces of Meat and Animal Carcasses.” *J. Food Safety* 15,:229-238.

Stanfos, Inc. September 1997. Personal communication with Lang Jameson, company representative, Edmonton, Alberta, Canada.

U.S. Department of Agriculture. July 1996. Food Safety and Inspection Service (USDA/FSIS), *Pathogen Reduction: Hazard Analysis and Critical Control Point (HACCP) Systems, Final Rule*, Washington D.C.:a.

U.S. Department of Agriculture. July 1996. Food Safety Inspection Service (USDA/FSIS), Supplement: Final Regulatory Assessment for Docket No. 93-016F *Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems*. Washington, D.C.:b.

USDA/FSIS. June 1996. “Nationwide Pork Microbiological Baseline Data Collection Program: Market Hogs”.

Unnevehr, L. J. and H. H. Jensen. August 1996. “HACCP as a Regulatory Innovation to Improve Food Safety in the Meat Industry.” *Am. J. Ag. Ec.*, 78:764-69.

## Endnotes

[1] We are grateful to the following companies for sharing information with us: CHAD Co. (3), Stanfos Inc. (23), Jarvis Co. (12), and Birko Co. (1).

[2] Two issues confound comparability among pathogen reduction studies. First, some studies observe pathogen levels in plants, which are generally low, and therefore observed reductions are also small. Other studies innoculate carcasses with high levels of pathogens in order to observe measurable and significant reductions following interventions. Second, few studies consider all possible combinations of interventions that a plant might consider, including the use of interventions at different points in processing

[3] Other studies of rinses and sprays (6, 7, 8) show comparable reductions for *salmonella* and *campylobacter*, so the Dickson (5) results may be taken as representative of these kinds of controlled laboratory experiments. As the pasteurizer is a very new technology, we have only the Gill, Bedard, and Jones (9) study as evidence. We do not have data regarding the steam vacuum.

[4] See Jensen, Unnevehr, and Gomez (13) for a similar analysis of pathogen reduction technologies in beef.