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Interdisciplinary Approaches to Food Safety Research: Opportunities for Partnership

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Material from two interdisciplinary research projects, conducted by the Center for Food Safety at Texas A&M University (one completed, one ongoing), is presented. These international projects respectively assess the comparative costs of adopting various pathogen reduction strategies in beef slaughter plants in Australia and the food safety risks (and recommended strategies to alleviate any risks) in cantaloupe and cabbage production and packing in Texas and Mexico. The economic component of each project is introduced, along with findings (for the completed project) and methodologies to be adopted (for the ongoing project). The vital role of stakeholders in conducting this research is stressed to provide lessons for similar partnerships in the future.

Introduction

Following increasing calls to better understand and analyze the impacts of food safety efforts (both mandatory and voluntary), a growing awareness of the need to conduct sound and inclusive interdisciplinary research over key academic and applied areas has arisen. This paper discusses such efforts being conducted at the Center for Food Safety at Texas A&M University. A multidisciplinary research team has been formed to help stakeholders and industry partners assess recent challenges and opportunities presented by food safety regulations and related innovations. The findings of the projects will encourage the adoption of those food safety interventions that are found to be both efficient and effective.

This paper presents material from two such international projects that span the mandatory and voluntary divide. The first considers efforts to strengthen quality assurance (QA) systems via the adoption of enhanced pathogen reduction strategies in beef slaughter plants in Australia. In part this is in response to the U.S. Department of Agriculture's (1996) *Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems; Final Rule*. The United States is a sig-

nificant market for Australian beef, representing about one-half of the value of all Australian agricultural exports to the United States. Australia is the ninth largest agricultural importer to the United States (by value). Further, there are increasing calls by Australian stakeholders (for example, the large supermarket chains) to update the domestic beef slaughter and processing industry. Such investments in pathogen reduction strategies may be considered "quasi-voluntary" responses; any company wishing to service this market may undergo such strong customer pressure to adopt a particular strategy that the option is hardly voluntary (Caswell, Bredahl, and Hooker, 1998). In such situations, the selection of a particular intervention may have surprisingly little to do with the cost or efficacy of the food safety intervention.

The second project similarly addresses quasi-voluntary reactions in the production and packing of fresh fruit and vegetables in the United States and overseas. Two main institutional "drivers" are motivating such research. First, recent U.S. Food and Drug Administration (FDA, 1999) guidelines have defined a voluntary set of minimal good agricultural practices/good manufacturing practices (GAPs/GMPs) for produce. Second, there have been increasing concerns raised over the relative safety of imported and domestic fresh and minimally processed fruits and vegetables (see, for example, Zepp, Kuchler, and Lucier, 1998). Surprisingly little research that evaluates the scientific basis and economic impact of these drivers exists to date. The efficacy and efficiency of "recommended" controls (be they GAPs/GMPs or increased surveillance at national borders) are yet to be fully evaluated. This second, ongoing, research project attempts to address this information short-

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fall. Two model crops, cabbage and cantaloupe, are used to test the following hypothesis:

Irrigation method, water source, worker hygiene, and washing practices in the field and packing shed can be manipulated to minimize contamination of cabbage and cantaloupes with human pathogenic organisms.

The research discussed in this paper is based in the Center for Food Safety, Institute of Food Science and Engineering, Texas A&M University. The Center is an interdisciplinary, multi-departmental, and multi-college grouping of some 50 core and affiliate faculty. The Institute, through its various centers, encourages partnership efforts by researchers and practitioners on- and off-campus, thereby facilitating a classic outreach or extension role.

To some extent, the two studies discussed here utilize agricultural economics as an integrating subject, bringing together technical (microbiology) research, extension, industry, and government partners to address specific applied problems. The paper will discuss the background and goals of the two projects. Summary findings for the Australian study and plans for the produce study will then be discussed. Finally, the vital role of communication with partners, both during and upon completion of the projects, is stressed below.

Problems Studied

Beef Slaughter

An increasing range of carcass pathogen reduction strategies is becoming available for beef slaughter plants. Much of the effectiveness research of these strategies has been conducted in the United States and Europe in plants that are significantly different to those seen in Australia. Therefore, the Meat Research Corporation and, later, the newer organization—Meat and Livestock Australia—(both industry associations representing red meat production, slaughter, and processing firms) commissioned a research project that would present an update of previous research applied to the Australian environment.

This project required a partnership between MLA and its members, Texas A&M University, AACM (a consulting firm in Australia), and vari-

ous industry experts representing the complete beef supply chain.¹ Meat and animal scientists, food microbiologists, veterinarians, and agricultural economists together considered the selection of effective and efficient pathogen reduction strategies for Australian beef slaughter plants via a comparative cost analysis of individual strategies and various combinations of strategies designed to decontaminate carcasses. The interventions that were evaluated included various cleaning (traditional trimming of visible contaminants, hand-held steam vacuums, and water rinses) and sanitizing (steam and acid cabinets; hot water rinses) regimes. Information from the meat science literature, laboratory-level evaluations of various interventions, pilot-plant tests, and commercial facility experiences were combined to provide the efficacy data. The cost data were constructed from a review of recent food safety economics research and information collected from key equipment supply companies. This was validated against current practices derived from a combination of on-site interviews, questionnaires, and a mail survey instrument administered to abattoirs. The direct additional fixed and variable costs and microbiological benefits of each intervention, solely due to the strategy under consideration, were used to demonstrate efficiency. As food safety benefits arise primarily from safer food and are evident at the societal (public) level, one must assume that particular plant level improvements represented by microbiological log₁₀ reductions will be observed and can be aggregated to the public level.

A comprehensive review of the available literature quickly indicated that no single source, or indeed combination of sources, could provide the information necessary to conduct an up-to-date consistent and accurate comparative cost analysis of pathogen reduction strategies for beef carcasses. Indeed, the research team was not able to identify a strong enough description of current industry practices as they relate to microbiological food safety issues nor even of industry structure. Therefore, an industry survey was undertaken to ensure that accurate production assumptions for the costs could be made. The methodology for the development, administration, and analysis of this survey is discussed below.

¹A more complete discussion of this project can be found in Markarian et al. (2000).

An exhaustive survey development process was adopted to ensure that all issues and concerns of partners were incorporated. This process involved pre-testing and the review of a draft instrument by the research team, plant managers, and industry experts. The final mail survey instrument included 54 questions divided into four sections. Respondents were asked to indicate current pathogen control strategies used, costs of implementation, and their impacts on the whole slaughter process. The second section focused on the QA systems in use, their implementation costs and in-plant effects, and impact on supplier/customer relations. The third section concerned identity preservation (the ability to "traceback" a product's production and processing history) while the final section collected production indicators, such as throughput, sales, capacity, etc.

The frame from which the survey sample population was selected was based on various industry sources, with a special effort being made to include all major beef abattoirs. A final sample of 98 plants was selected from the population of organizations comprising the Australian beef processing industry. Given the relatively small number of plants available, each processor was selected to maximize the likelihood of response whilst still retaining sample diversity in terms of plant location, throughput, and market orientation.

Given the complex nature of the livestock-beef supply chain and the variety of firms in-

involved, the research team made a special effort to visit partners with diverse plants and to meet with individuals knowledgeable of as many types of operations as possible to augment the data collected by the survey. This required discussions with various public and private partners—including industry associations, government agencies, and research bodies—and supermarket buyers. Finally, and of great importance to the research, the team met with and/or telephoned each of the key equipment supply companies to ensure that accurate product information was included.

Fruit and Vegetable Production and Packing

In Texas, 11,000 acres are dedicated to the production of cabbage, yielding an annual production value of \$31.6 million. Muskmelons (which include cantaloupe and honeydew) are grown on 16,500 acres, with a production value of \$53.4 million per year. The relative importance of these crops in U.S.-Mexican trade is suggested in Table 1, demonstrating a steady volume of cabbage imports and a tripling of the value of cantaloupe trade between 1994 and 1998 (post-NAFTA).

We seek to better understand the impact that certain production and packing steps have on the contamination of these commodities with pathogenic organisms and to identify intervention strategies that can be introduced either as new methods or as modifications of existing ones to improve the safety of these products.

Table 1. Value and Volume of Cabbage and Cantaloupe Trade from Mexico to the United States.

	1993	1994	1995	1996	1997	1998
Cabbage						
Volume (Mt)	8,422	6,009	10,411	11,656	11,777	11,472
Value (\$1,000)	1,523	1,126	1,979	2,025	2,123	2,906
Cantaloupe						
Entered 8/1–9/15						
Volume (Mt)	n/a	n/a	23	106	912	470
Value (\$1,000)	n/a	n/a	46	33	205	87
Entered 9/16–7/31						
Volume (Mt)	68,275	66,840	101,798	146,040	151,320	153,705
Value (\$1,000)	17,691	19,182	28,781	46,036	55,416	57,000

Cabbage: fresh or chilled.

Cantaloupe: fresh.

Source: USDA/ERS (1999); Whitton (personal correspondence).

Beuchat (1996) published a useful review that discusses the possible mechanisms whereby fruits and vegetables can become contaminated. In the review, he explained that the contamination of produce with pathogens could originate from the soil in which the crop is planted, which itself can be contaminated with fecal material from animals and humans. In addition, the water that is used to irrigate and/or wash the produce can contribute to the contamination level since it also can harbor organisms from feces as well as from other sources. The handling of produce, both in the field and packing shed, can also add bacteria through the fecal material of workers, as well as from cross-contamination with surfaces and foods containing pathogens. There is limited evidence of the difference in production and processing methods between the United States and Mexico. Thus, it is unclear if additional risk management interventions are appropriate for this trade. Finally, the relative efficacy and efficiency of pathogen reduction strategies (for example, in-field washing, worker training, or additional water treatment in the packing shed) have yet to be assessed.

Cabbage and cantaloupe have been implicated in significant outbreaks of foodborne illness. Both are consumed raw or are minimally processed and may therefore pose significant food safety hazards. In the case of cabbage, an outbreak that took place in Canada is the most well-known, with 34 cases of perinatal listeriosis and seven additional cases of the adult form being reported after the consumption of coleslaw contaminated with *Listeria monocytogenes* (Schlech et al., 1983). Melons have been involved in several outbreaks of foodborne illness, with salmonellae as the causative agent. A very large outbreak, estimated to involve more than 25,000 cases, occurred from the consumption of salad-bar cantaloupe contaminated with *Salmonella* serotype Chester (Ries et al., 1990). Approximately 30 states were involved, and it is believed that the product may have originated from Texas. Another outbreak attributed to cantaloupe took place just a year later, with almost 200 individuals infected in 23 states as well as in Canada. In this episode, the serotype Poona was singled out as the culprit (CDC, 1991). As in the case of a year earlier, some melons may have originated from Texas.

Hurst and Schuler (1992) mention water quality as one of the most important issues in maintaining

the safety of fruits and vegetables. Thus, in any attempt to improve the safety of these commodities, one must consider intervention strategies that improve the quality of the water used for irrigation and other purposes, especially inside the packing shed. In addition, the method of irrigation may play a role in the contamination of crops. Furrow irrigation is utilized in most cabbage and melon operations in the Texas Rio Grande Valley and in several production areas in Mexico. Two other methods are the drip and the pivot, both of which result in water coming into direct contact with the crops, which may act as a source of contamination. Water is also employed to wash crops after harvest, with chlorine often being used as an added disinfectant in the packing shed.

Findings for the Beef Study

Microbiology Component

The first microbiological milestone report provided MLA with a thorough literature review of published experimental work in the area of carcass decontamination. The topics that were covered ranged from carcass cleaning methods, such as water washing, to carcass sanitation methods, such as ionizing radiation. Aspects such as time of application, temperature effects, tissue effects, and other issues are also considered. In addition, the state-of-the-knowledge regarding application of these treatments, in combination, was also discussed. Based on published literature, the document concluded with the best treatments that achieved maximum reduction of microbial contaminants. Subsequent milestones reported on the laboratory and pilot plant evaluations of the various independent and combination interventions determined to be most appropriate, based on the literature review and preliminary assessments. Finally, a number of industry-level trials were conducted with these results being directly compared to those found by the team in more controlled environments.

Of the soil removal strategies (washing vs. trimming vs. steam vacuum), trimming resulted in the highest reduction in total aerobic plate counts (\log_{10} 3.4-5.2), followed by steam vacuum (\log_{10} 2.5-3.1), followed by water-washing (\log_{10} 1.3-2.0).² However, it was observed that these rank-

²Aerobic plate count (APC) \log_{10} reductions provide the total number of organisms (bacteria, yeast, and mold) present in a food sample, following an intervention compared to a control sample. Although not representing pathogen reductions *per se*, APCs are often used as an indicator of efficacy in microbiology.

ings were very dependent on the accuracy of the trimming operation, reliable only if the contamination were visible. No correlation was seen in terms of the efficacy of soil-removing treatment, according to type of beef cut (outside round vs. brisket vs. clod).

In examining the effectiveness of decontamination strategies, the application of 2 percent lactic acid alone resulted in the highest reduction in APC (\log_{10} 5.4-6.1 after trimming), followed by hot water alone (\log_{10} 4.7-5.7 after trimming). Application of both treatments (lactic acid and hot water) did not offer significant advantage over lactic acid alone, with reductions of \log_{10} 5.0-5.1 for hot water + lactic acid and of \log_{10} 4.7-5.6 for lactic acid + hot water. Thus, the best treatments consisted of trimming, followed by 2 percent lactic acid alone. Incidentally, this treatment achieved a \log_{10} reduction of at least 5.0 for both pathogens studied.

Economic Component

The various efficacy and cost data collected were combined and validated against the current practice information from the survey and interviews. This process identified two main categories of plants (export and domestic) and three sizes (small, medium, and large). One method that was utilized to demonstrate the research results is presented in Figure 1. Each data point is a cost- \log_{10} reduction pairing over the various independent and combination strategies considered. Grouping each plant size over the full range of interventions allows the construction of trade-off curves that indicate both returns to scale in food safety controls and the more obvious increasing costs of pathogen reduction.

Plans for the Produce Study

Microbiology Component

The project will utilize a two-phase approach, with Phase I consisting of identifying current practices and evaluating them in terms of their impact on contamination of cabbage and cantaloupes (see Figure 2). Based on preliminary advice from extension specialists, we will focus primarily on the following practices: method of irrigation (furrow vs. pivot vs. drip); source of irrigation water (untreated aquifer, untreated river, treated water); worker hygienic practices; and washing

practices in the field and packing shed. Several Mexican production areas and two distinct regions in Texas will be studied.

Phase II will consist of identifying intervention strategies that can be applied to minimize contamination, based on results from Phase I, and testing these strategies in an experimental farm. These practices, tested in Phase I, that yield the lowest incidence of pathogenic contamination will be evaluated. In addition, the effectiveness of several product-washing treatments that can be applied in the field to decontaminate cabbage and cantaloupes will be tested.

Sampling will be carried out once in the winter and once in the summer to determine whether seasonality plays a role in the sources and level of contamination, type of practices, cost, etc. Microbiological testing of product samples (1) just prior to the final irrigation, (2) after the final irrigation, (3) immediately after harvest (before washing and packing), and (4) after washing (in the field and/or at the packing-house). Water samples and temperature, humidity, crop and ambient temperatures will also be collected at each stage.

Experimental farms, which belong to Texas A&M University at the Weslaco Center, will be utilized for the evaluation. In addition to testing irrigation practices and worker hygiene, we will determine the effectiveness of various washing methods that can be applied, either in the field or at the packing shed. The treatment combinations will consist of washing with chlorinated water once versus twice, and washing with lactic acid only versus washing with chlorinated water followed by lactic acid. Method of application will be tested (dipping versus spray) as well as temperature of the wash (25°C versus 35°C).

We will also evaluate the hygienic conditions of the packing containers and the transport trucks in order to determine their role in the contamination of the product. For this, we will sample the product after packing and after it is transported to its destination (retail) as well as the contamination level of the packing boxes and the transport trucks themselves.

Economic Component

A survey of producer and packer members of the Texas Produce Association and their counterparts in Mexico will be carried out to identify current production practices. Detailed production and

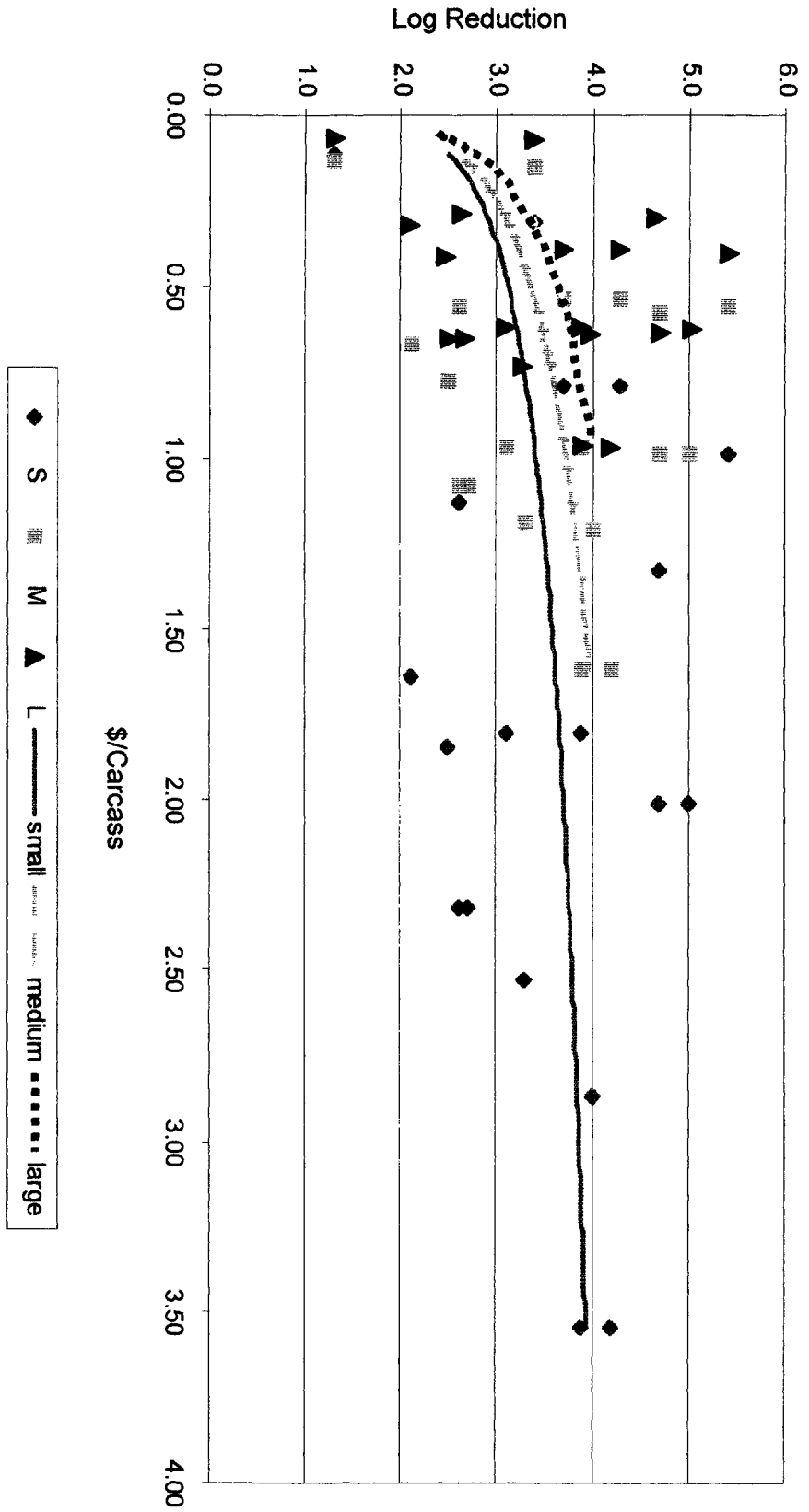


Figure 1. Total Cost and APC Log Reductions and Trade-off Curves—Export Plants.

Identify Current Practices in Texas and Mexico	Sample -Water -Produce -Field -Packing Shed	Monitor -Environment -Production Costs
Identify and Test Intervention Strategies at TAMU Experimental Farm	Determine Costs and Marketing Impacts of Interventions	Develop Technology Transfer Vehicles and Administer to Partners

Figure 2. Experimental Plan for Cabbage and Cantaloupe Study.

marketing data will be collected during Phase I from those producers and packing sheds sampled. This information will complement that collected from the mail survey of producers in Texas and Mexico as well as that provided by the produce associations. The factors to be considered will include seedling source, crop density, frequency and duration of irrigation, and picking and packing costs (labor, materials, and distribution aspects). Cost estimates for each of the intervention strategies assessed in Phase II will be constructed, paying particular attention to scale and scope issues (for example, size of farm, single- versus multiple-crop, growing season, and irrigation source). Additional costs incurred due to washing (for example, spraying units, labor, wastewater collection, and disposal, etc.) will form the basis of this analysis. During the second year (growing season) of the study, a follow-up survey instrument will be distributed, questioning firms about any changes in production or packing practices.

This information will be combined with a more general analysis of the marketing channels for cabbage and cantaloupe in Texas and Mexico following contributions from the produce associations and key customers (for example, distributors and retailers). This will allow the research team to better assess potential benefits (for example, price premiums, secured and expanded markets, reduced levels of product rejections, reduction in foodborne illness associated with cabbage and cantaloupe) of those intervention strategies demonstrated to be most effective.

Communicating the Results

Given the close working relationship between the research team and partners in the beef study,

we were able to communicate initial results as the project progressed. More formal communication included various milestone project reports, indicating microbiological and economic literature reviews, pilot plant and commercial-scale evaluations of the pathogen reduction strategies, and quarterly updates. These reports were presented to MLA, with summaries forwarded to their member-partners.

An important communication tool adopted with the survey results was the presentation of an industry synopsis that allowed all respondents to "benchmark" their answers to those of their counterparts in the industry. The final project report has again been submitted, with an industry summary version currently being completed, to serve as an immediate resource to all industry partners. It is important to maintain a close dialogue with all partners throughout the research.

For the cabbage and cantaloupe study, an industry advisory board is being formed. Those companies providing in-kind contributions (time, coordination efforts, and produce sampled), as well as other industry representatives, will participate. Meetings will be held once per quarter and will serve to provide industry with an update of activities and findings and to acquire their expert advice on work to be done. The research team will also attend the annual meetings and conventions of the partner industry associations to communicate the goals and interim results of the project to a wider partner audience. Once again a survey synopsis will be returned to all respondents following each mailing. This will allow firms to benchmark current practices.

A formal project report will eventually be prepared, both in scientific and lay language, at the

end of the two-year project. The report will be delivered to the industry through the produce associations in partnership with Texas A&M University. In addition, distribution will also be conducted through the Texas Agriculture Extension Service and analogous partners in Mexico. The vehicles of delivery will include printed reports and postings on the Internet at the websites of the Texas A&M Center at Weslaco and the Center for Food Safety. A public conference, which will be held in San Antonio, Texas, will be organized at the conclusion of the project. The impact that the presentation has on the participants will be ascertained through written evaluations filled out by participants at the conference.

An Advertisement

Finally, the authors are currently compiling a collection of approximately 10 similar interdisciplinary food safety research projects. We will be publishing a book on this topic, presenting the experiences of other research teams and how they have managed to combine advances in research techniques across a number of fields including food, animal, and veterinary sciences; food microbiology; agricultural economics; marketing; sociology; law; policy development; and risk management. The food safety topics addressed in these chapters will encompass risk analysis techniques, industry experiences with food safety and quality assurance systems, and consumer perceptions of food safety. The book, to be published by CRC Press, will be available in the fall of 2000.

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