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A 4-Year Intervention to Increase Adoption of Safer Dairy Farming Work Practices

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Background *Traumatic and musculoskeletal injury rates have been high in dairy farming compared to other industries. Previous work has shown that social marketing efforts can persuade farm managers to adopt practices that reduce injury hazards compared to traditional practices if the new practices maintain profits.*

Methods *The intervention disseminated information to 4,300 Northeast Wisconsin dairy farm managers about three safer and more profitable production practices (barn lights, silage bags, and calf feed mixing sites) using information channels that these managers were known to rely on. We evaluated rolling, independent, community-based samples, at baseline and then again after each of four intervention years. We also evaluated samples from Maryland's 1,200 dairy farms after the second through the fourth year of the intervention. Maryland dairy managers read many of the same nationally distributed print mass media that we used in the intervention and so were a "partially exposed" comparison group.*

Results *The intervention to disseminate information about the innovations was successful. In comparisons before and after the intervention, Wisconsin managers reported getting more information about calf sites from public events and equipment dealers, about silage bags from other farmers and equipment dealers, and about barn lights from public events, other farmers, equipment dealers, consultants, and electrical suppliers. Wisconsin managers also reported getting more information than Maryland managers from public events for barn lights and silage bags. During years three and four, the intervention managed to sustain, but not improve, earlier increases in adoption and awareness from the first 2 years. After adjusting for farm manager and operation variables, intervention years was associated with increased Wisconsin manager adoption of two of three practices in comparisons between the baseline and the fourth intervention year: barn lights (odds ratio = 5.58, 95% confidence interval = 3.39–9.17) and silage bags (OR = 2.94, CI = 1.84–4.70). There were similar results for awareness of barn lights and the calf feeding sites. Compared to Maryland managers, Wisconsin managers reported greater awareness of barn lights.*

Conclusions *Disseminating information to managers through information channels that they usually consulted was associated with increased reports of getting information and with greater adoption and awareness of safer, profit-enhancing work practices in a high hazard industry.* Am. J. Ind. Med. 54:232–243, 2011. *© 2010 Wiley-Liss, Inc.*

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INTRODUCTION

Nationwide, there were 71,510 dairy operations in the US in 2007 [USDA, 2009]. Annual rates of fatal and nonfatal occupational injury in dairy farming have long been higher than those for production agricultural overall and as much as three to six times higher than average rates for all US private industries [Gerberich et al., 1993; Myers and Hard, 1995; Myers, 1998; NIOSH, 1998; Hard et al., 2002]. Previous research among dairy producers has shown that the most common source of fatal traumatic injury was tractor operation (e.g., rollovers, power take off entanglements) [Skjolaas et al., 2005]. Animals have been the most common source of nonfatal injuries in dairy farming (e.g., kicked by cow, stepped on by cow, and crushed against barn structure) [Pratt et al., 1992; Hard et al., 2002; Douphrate et al., 2009]. Another source of fatal and nonfatal traumatic dairy farm injury has been tower silos (i.e., falls from elevation, machinery entanglement, and suffocation) [Josefsson et al., 2001]. Falls on the same level have also been an important cause of injury in dairy farming. Research has shown that most cases occurred in the milking area or barn, most falls resulted from slips, most slips involved concrete, and most concrete slips involved underfoot hazards of manure, urine, and/or water that made the concrete slick [Bentley et al., 2005]. Visual demands were the principal factor explaining why underfoot hazards were not detected in most falls, often in association with insufficient illumination.

Although harder to document, dairy farming also appears to be associated with high rates of musculoskeletal disorders with some studies showing over 80% of milking workers reporting musculoskeletal discomfort at some time over the last year [Pinske, 2003; Nonnenmann et al., 2008]. Previous research to assess all the tasks routinely performed in dairy farming has shown that feeding and milking required the highest energy expenditure levels on loose housing dairy operations with milking parlors while feeding and manure handling were highest on more traditional tethered cow housing operations with milking-in-place systems [Ahonen et al., 1990; Perkio-Makela and Hentila, 2005; Kolstrup et al., 2006]. Neck and upper extremity disorders were common in parlor milking (where workers stand and reach), while back, hip, and other lower extremity disorders were more prevalent in operations with milking-in-place systems (where workers squat) [Kolstrup et al., 2006]. On dairy operations in Wisconsin and other traditional agriculture states in the North Central and Northeast US, calves have been housed in individual shelters some distance from the dairy barn to improve their survival. The task of feeding calves housed this way often requires workers to repeatedly lift and carry heavy loads in buckets for what can be considerable distances twice a day [Josefsson et al., 1999c]. Calf feeding work has been anecdotally associated with musculoskeletal problems.

Individual farm managers successfully adopting more profitable technological innovations has long driven improvements in agricultural productivity [Rogers, 2003]. Agriculture has led other US industries in productivity improvement. Between 1948 and 1994, for example, total factor productivity growth for US agriculture was 1.94% annually compared to 1.31% for US manufacturing [Ahearn et al., 1998]. Previous research has also shown that better information flow to farm managers can speed this adoption of more profitable production practices [Feder and Umali, 1993; Wejnert, 2002; Rogers, 2003].

Promoting safer practices that are also more profitable may be a useful interim strategy in the absence of more comprehensive occupational safety regulation for the small business agricultural operations that currently escape effective regulation and enforcement [Murphy, 1992; Kelsey, 1994; McCurdy and Carroll, 2000]. A large body of previous work supports the effectiveness of promoting more profitable agricultural practices through social marketing and using existing social and information networks [Rogers, 2003]. Other studies have evaluated the adoption of work practices in agriculture that were both safer and more profitable [Chapman et al., 2004; Davis and Kotowski, 2007]. At least one previous study has successfully promoted safer work practices that are also more profitable among dairy farmers [Lundqvist, 1996]. Successful interventions have tended to be those that provided persuasive, short format information about specific, proven practices that were easy to adopt and did not interfere with efficiency [Lundqvist, 1996; Rogers, 2003; Chapman et al., 2004]. Published reports that conduct multiyear interventions with large groups of agricultural managers are uncommon in peer-reviewed journals.

We conducted a 4-year long intervention effort that sought to improve information flow to increase awareness among dairy farm managers about three production practices that were both more profitable and safer than traditional work practices and to persuade the managers to adopt them. The practices were designed to reduce or avoid hazards leading to traumatic and musculoskeletal injury. Earlier reports we published after the first and second years of our intervention documented some increases in practice awareness and adoption [Chapman et al., 2003, 2009b]. In this article we present awareness and adoption results after four intervention years.

METHODS

Study Design and Conceptual Model

The intervention plan incorporated a well-known theoretical model and previous research findings about how and why individuals adopt agricultural technologies [Feder and Umali, 1993; Wejnert, 2002; Rogers, 2003]. In the model, the farm manager proceeds through three stages in a sequential fashion: from unaware to aware to adopt based on information flow. Previous research has shown that increased information flow can increase the speed and geographic prevalence of awareness and adoption and that the most efficient way to provide information flow is through social networks and other information sources familiar to and trusted by managers [Rogers, 2003].

Subjects

The intervention treatment group was the managers who made the day to day decisions on all dairy operations in eight, geographically contiguous Northeastern Wisconsin counties (n = 4,300). We used an updated governmental list of all dairy operations in the state as our primary sampling frame for each year [i.e., Wisconsin Department of Agriculture, Trade and Consumer Protection, 1997–2001]. Because Wisconsin has many relatively small operations and the government list did not include operation sizes, we supplemented our population-based, simple probability samples in the evaluation with separate oversamples of larger dairy farms from membership lists of the Wisconsin Dairy Herd Improvement program [Ag Source Cooperative Service, 1996–2001]. We drew independent samples of 100–300 of the largest operations in the eight counties from the membership lists each year and then combined and reconciled the two samples so there were no duplications and no repeats from previous years' mailings. We took this step so that our findings could better reflect the experience of larger sized dairy producers nationwide. We mailed evaluation questionnaires to rolling, independent probability samples (a different group each year) of 597 managers in Northeast Wisconsin at baseline, and then to 352–587 per year over the next 4 years.

Beginning at the end of the second intervention year, we used a list of all Maryland dairy producers to obtain rolling, independent comparison group probability samples [State of Maryland Department of Agriculture, 1999–2001]. We mailed evaluation questionnaires to comparison group samples ranging from 200 to 299 after the second through fourth year of the intervention. Additional detail on the subjects, sampling frames, and sampling procedures is available elsewhere [Chapman et al., 2009b].

Production Practices

This project's researchers consulted with university Extension dairy specialists and the published literature to identify promising work practices. After selecting the dairy work practices (e.g., tools, equipment, and facilities) that had the greatest potential to improve both safety and work efficiency, the project's research team used existing evaluations and conducted some work of our own to identify, quantify, and compare the hazards and costs of the promising practices with the conventional practices [e.g., Josefsson et al., 2001, 1999a,b,c]. Practices that were both reasonable in cost and that made important improvements in work efficiency were prioritized so they would be attractive and practical for most small-scale operations. The selected practices focused on three less common but typical sources of traumatic and musculoskeletal injury hazards. In choosing the practices, some of the other criteria taken into consideration included (1) whether the safer practices were relatively new to the industry (i.e., not already widely known), (2) whether the concept of the practice was easy to describe in our outreach materials and methods, and (3) the extent to which the safer practices reduced important work hazards to which high proportions of the workforce were exposed. The three production practices that the intervention promoted were:

Barn lights: Many dairy animals spend most of the year inside poorly lighted cow barns [Chastain and Hiatt, 1994]. From October through March, scheduled supplemental lighting of dairy livestock housing that simulates summer day lengths and light intensities has been demonstrated to biologically increase cow milk yields and heifer growth by 5–15%. For most operations, the return on investment is 1–2 years [Peters, 1994; Dahl et al., 2000]. Supplemental lighting can improve safety because poor lighting and visibility is known to increase the risk of slips and falls on the same level in the barn, animal contact injuries, and vehicle collisions with barn structures [Bhattacharya, 1998; Josefsson et al., 1999a, 2001; Davies et al., 2001].

Silage bags: Winter feed for cows has traditionally been stored in tower silos. Silage storage in long, tubular plastic bags on the ground compares favorably to both traditional tower silos and to newer bunker silos in terms of capital investment, operating costs, and silage quality. Payback periods can be 1 year or less, depending on how extensive and how recently investments were made in bunkers or towers [Josefsson et al., 1999b]. Storing silage in bags also largely eliminates the dangers of silo gas and of falls from climbing tower silos as well as machinery entanglement hazards from tower silo unloaders. Furthermore, silage bags reduce or eliminate hazards associated with bunker silos, including tractor rollover

during loading, silage face collapse suffocations, and falls from elevation [Josefsson et al., 2001].

Calf feed mixing sites: Dairy herd calves have traditionally been housed in hutches or other structures at some distance from the cow barn because this reduces infectious diseases and otherwise significantly enhances calf survival and growth. A mixing and storage facility for liquid and solid calf feed that is immediately adjacent to the calf housing area can measurably reduce feeding time and labor requirements with payback periods of 1–5 years [depending on operation size Josefsson et al., 1999c]. A calf feed mixing site is also likely to lower the risks of back and other musculoskeletal injuries by reducing lifting, carrying, and other manual materials handling because feed is available in much closer proximity to calf housing sites and because employee time exposed to these musculoskeletal hazards is reduced [Josefsson et al., 1999c].

Intervention Information Dissemination Components

Before we began our intervention, we reviewed previous research about which information sources agricultural producers generally, and Wisconsin dairy managers in particular, used and trusted [Fett and Mundy, 1990; Smith, 1995]. In our baseline questionnaire administered prior to the intervention, we asked Wisconsin dairy managers what information sources they used and how much they trusted them [Chapman et al., 2009a]. Based on these findings, we planned and conducted our information dissemination intervention to emphasize the sources that were used most often and trusted most highly.

Print mass media

Over the 4-year intervention period, we assisted dairy trade publication journalists in writing their own articles about the three practices we promoted by sending them biannual press packets that included short format print materials (e.g., http://bse.wisc.edu/hfhp/tipsheetpage.htm), photos, and lists of potential telephone interview contacts. We tracked articles about our three work practices that appeared in print media (agricultural newspapers and dairy trade publications) in the year before and during the 4 years of our intervention. We also used standard methods to determine annual column inches of coverage [Treno et al., 1996].

Public events

We provided materials and other assistance about the three practices to university Extension agents and other public and private sector resource people who were mounting exhibits, staffing booths, delivering presentations, or otherwise disseminating information at local and regional field days, farm shows/expositions, and other events traditionally attended by dairy farmers. We tracked attendance at events that promoted our practices and followed up by phone at events where our project staff was not present to find out how our materials were received.

Resource people

We mailed short-format print materials about each practice to the region's 9 university dairy and livestock extension agents, 4 farm equipment dealers, 46 dairy veterinarians, 6 farm electrical suppliers, and to farm consultants for them to distribute during their farm visits and group programs.

Farmer-to-farmer exchange

We recruited six dairy farm managers in northeastern Wisconsin who were already using the practices to cooperate with the intervention. We encouraged other farm managers and agricultural journalists to contact and visit them.

Internet-based outreach

Beginning in the third year of the intervention, we maintained a website where noncopyrighted materials about each practice were freely available (http://bse.wisc.edu/hfhp/). We announced the website via postcards that we sent to resource people and included our website listing on business cards, letterhead, exhibits at public events, and all our printed materials.

Evaluation Questionnaire Administration and Procedure

We developed and administered a mail questionnaire based on standardized recommendations that required about 20 min to complete [Salant and Dillman, 1994; Dillman, 2000, 2006]. The cover page requested that the questionnaire be filled out by the farm operator or the person who made the most dairy farm management decisions. The accompanying cover letter emphasized the social utility of the questionnaire, the importance of each respondent completing it, and privacy protections. We conducted a series of follow-up mailings to nonrespondents, including a reminder postcard 8–14 days later and repeated remailings of the questionnaire and cover letter at about 24 and again at 35 days afterwards. In the baseline mailing administered prior to the intervention, the cover letter told subjects that a drawing would be held and one of every three individuals who returned complete questionnaires would receive their choice of a selection of

personal protective equipment items valued at $10–12 (e.g., sun hat, hearing protectors, and boots). In the four annual mailings after the first through the fourth intervention years, all respondents were promised and received 10 first-class postage stamps as an incentive. The protocol was approved by the University of Wisconsin-Madison College of Agricultural and Life Sciences human subjects committee. The questionnaire administration protocol was deemed exempt so no informed consent signatures were required.

Data Analysis and Hypotheses

Questionnaires with all pages at least partially completed were coded and entered into a database. All questionnaires were manually checked to verify the accuracy of data entry. The barn lights' logistic regressions excluded operations that failed to report using timers for their barn lights or that provided fewer than 6 hr of darkness each day. The calf feeding site regression and univariate analyses excluded operations that reported not raising calves or raising calves only in the cow barn. Our evaluation tested two hypotheses:

Did managers report getting more information? We used univariate statistics to investigate whether Wisconsin farm managers' reports of getting information changed during the course of the study (baseline data were compared with data collected after intervention year 4) and whether reports of getting information differed between Wisconsin and Maryland managers (data from the fourth intervention year in Wisconsin were compared with the Maryland data from that year). The Pearson's chi-square test (two-sided) was used to compare percentages and Student's *t*-test (two-tailed) was used to compare numerical values after Levene's test for equality of variances [SPSS, 1996]. The significance level was set at $P \leq 0.05$. No adjustments were made for multiple statistical comparisons.

Did managers report more adoption and awareness? To assess the main research question, we used logistic regression to generate a total of six equations: one for adoption and one for awareness of each of the three production practices with the Northeastern Wisconsin data [Menard, 2002]. In each equation, the intervention year was modeled as a categorical variable whereby the first through fourth intervention years were compared with the baseline, pre-intervention year while controlling for manager age, education, gender, operation milking herd size, manager years of experience in dairy farming, gross sales, and manager reports of the percent of their operation that was owned debt-free. Operations that reported having adopted one or more of the three production practices in the baseline questionnaire prior to our intervention were excluded from the analysis for that work practice. The significance level was set at $P \leq 0.05$. Confidence intervals reported for awareness and adoption are all 95% confidence intervals. To investigate for differences between Wisconsin and Maryland manager awareness and adoption, we also used univariate Pearson's chi-square tests to compare data from the fourth intervention year in Wisconsin with Maryland.

RESULTS

Evidence That the Intervention Was Delivered

The barn lights practice received the most extensive print coverage followed by silage bags. Two articles totaling 30 column inches of coverage appeared in dairy print media about barn lights in the baseline year prior to the start of our intervention. During the four intervention years, 28 barn lights articles (totaling 736 column inches) were run. Similarly, one article (two column inches) was published during the baseline year and then 13 articles (409 column inches) about silage bags appeared. There were no articles during the baseline year about calf feeding sites. During the 4-year intervention, a total of five articles appeared (61 column inches). Our intervention also made information available to farm managers about all three practices through public events in Wisconsin (e.g., farm shows, expositions, and field days) at 41 events for barn lights and silage bags and 35 for the calf feeding sites. During the last two compared to the first two intervention years, the number of articles times their column inches decreased by 57% for barn lights (7,334 vs. 3,150), and decreased by 65% for the calf feeding site (120 vs. 42) but increased by 44% for silage bags (992 vs. 1,425). The number of public events where the practices were promoted remained essentially unchanged between the first two and the last two intervention years.

Questionnaire Responses and Sample Demographics

Wisconsin dairy manager questionnaire return rates ranged from 72% to 79% and exceeded Maryland managers, who returned 38% to 58% (Table I). For Wisconsin managers, samples at baseline were comparable to samples after year 4 for education and herd size but not for age, percent of managers who were female, or years as a dairy farmer which all increased. Gross sales last year decreased (see Table I). Aside from being better educated, the Wisconsin dairy managers were not significantly different from the Maryland dairy farmers after the fourth year of the intervention.

TABLE I. Wisconsin and Maryland Dairy Operation Evaluation Samples

Characteristic	Group	Year 0	Year 1	Year 2	Year 3	Year 4	*P*-value[a]
Questionnaires mailed	WI	597	587	422	394	352	
	MD	—	—	299	240	200	
No. returned (% of mailed)	WI	427 (72%)	428 (73%)	306 (73%)	295 (75%)	278 (79%)	
	MD	—	—	115 (38%)	114 (48%)	115 (58%)	
No. eligible (% of mailed)[b]	WI	411 (69%)	415 (71%)	300 (71%)	292 (74%)	267 (76%)	
	MD	—	—	115 (38%)	112 (47%)	112 (56%)	
Manager age	WI	45.1 ±11.0	45.8 ± 10.6	45.9 ± 9.9	45.9 ± 10.1	47.5 ± 10.7[f]	0.009
	MD	—	—	46.9 ± 12.0	47.2 ± 12.6	47.3 ± 12.8	0.871
Manager education (1–9)[c]	WI	4.0 ± 1.6	4.1 ±1.6	4.5 ± 1.8	3.9 ± 1.6	3.9 ± 1.7	0.309
	MD	—	—	3.81 ±2.2	3.5 ± 2.3	3.1 ±2.0[g]	0.001
Manager gender (% male)	WI	(394) 96%	(407) 96%	(270) 91%	(261) 89%	(242) 92%[h]	0.001
	MD	—	—	(108) 93%	(102) 90%	(100) 91%	0.724
Manager years in dairy	WI	28.6 ± 11.9	30.0 ± 11.8	30.5 ± 11.7	29.3 ± 11.2	31.3 ± 12.4[i]	0.025
	MD	—	—	32.4 ± 12.6	31.4 ± 13.5	32.9 ± 13.5	0.327
Herd size (no. cows)	WI	102.3 ± 97	116.6 ± 124	126.9 ± 203	101.5 ± 182	99.1 ±159	0.749
	MD	—	—	87.5 ± 75	97.6 ± 103	86.0 ± 66	0.406
Gross sales last year[d]	WI	3.9 ± 1.5	4.0 ± 1.5	4.2 ± 1.6	3.5 ± 1.6	3.3 ± 1.6[g]	0.001
	MD	—	—	3.6 ± 1.5	3.7 ± 1.7	3.3 ± 1.7	0.778
Injured w/medical last year[e]	WI	(37) 9%	(38) 9%	(35) 12%	(18) 6%	(19) 7%[h]	0.099
	MD	—	—	(6) 5%	(9) 8%	(9) 8%	0.759

WI, Wisconsin; MD, Maryland.

[a] *P* values for year 4 WI line are WI year 0 versus WI year 4. *P* values for year 4 MD line are for MD year 4 versus WI year 4. Calculations used chi-square for percent and Student's *t*-test for numerical values.

[b] Number eligible designates the number of questionnaires after those not reasonably complete or those returned for other reasons (e.g., no longer farming) were eliminated.

[c] Education scale: 1 = grade school, 2 = some high school, 3 = high school grad, 4 = high school plus vo/tech, 5 = some college, 6 = 2 years associate degree, 7 = 4 years college degree, 8 = some graduate school, and 9 = graduate degree.

[d] Gross sales scale: 1 = <$5,000, 2 = $5–15 k, 3 = $15–25 k, 4 = $25–50 k, 5 = $50–100 k, 6 = $100–200 k, 7 = $200–400 k, and 8 = >$400 k.

[e] Injured w/medical last year refers to the number of operations reporting injuries that required medical attention.

[f] $P \leq 0.01$.

[g] $P \leq 0.001$.

[h] $P \leq 0.10$.

[i] $P \leq 0.05$.

Did Managers Report Getting More Information?

Those dairy farmers who reported that they had seen, heard, or read about each practice in the last year were asked where they remembered obtaining this information. Compared to their baseline, after the fourth intervention year significantly more Wisconsin dairy farmers reported getting more information about calf sites from public events (20% vs. 28%; $P < 0.045$) and equipment dealers (3% vs. 8%, $P < 0.022$) and less from extension agents (9% vs. 4%, $P < 0.038$). They reported getting more information about silage bags from other farmers (67% vs. 77%, $P < 0.005$) and equipment dealers (bags 17% vs. 25%, $P < 0.012$) and less from extension agents (16% vs. 8%, $P < 0.002$). They reported getting more information about barn lights from public events (12% vs. 44%, $P < 0.001$), other farmers (24% vs. 39%, $P < 0.002$), equipment dealers (6% vs. 26%, $P < 0.001$), farm consultants (8% vs. 16%, $P < 0.011$), and electrical suppliers (9% vs. 34%, $P < 0.001$).

After the fourth intervention year, more Wisconsin than Maryland dairy farmers, reported getting barn lights information from public events (44% vs. 20%, $P < 0.001$), extension agents (18% vs. 4%, $P < 0.004$), and electrical suppliers (34% vs. 6%, $P < 0.001$). Wisconsin managers compared to Maryland also reported getting more silage bag information from public events (44% vs. 26%, $P < 0.001$), other farmers (77% vs. 61%, $P < 0.002$), and veterinarians (8% vs. 2%, $P < 0.033$). Maryland farmers reported getting more information than Wisconsin farmers about silage bags from equipment dealers (45% vs. 25%, $P < 0.001$).

Did Managers Report More Awareness and Adoption?

The multivariate logistic regression analyses simultaneously controlled for manager age, sex, education, years of

dairy farm experience, operation gross sales, herd size, and percent of operation owned debt free.

Adoption

Among the Wisconsin farmers, the intervention was associated with increased adoption of two of the three practices after the fourth intervention year: barn lights (odds ratio = 5.58, 95% confidence interval = 3.39–9.17), and silage bags (OR = 2.94, CI = 1.84–4.70) (see Table II). When other variables were held constant, higher operation gross sales was also associated with adoption for all three work practices. For barn lights, smaller operation herd size and for silage bags, younger manager age, and smaller percentages of the operation owned debt free were also associated with adoption (Figs. 1–3 and Table II).

Compared to Maryland farmers, there were no differences in Wisconsin farmer reports of adoption after the fourth year of the intervention for any of the three practices.

Awareness

The intervention was associated with increased awareness among the Wisconsin farmers for two of the three

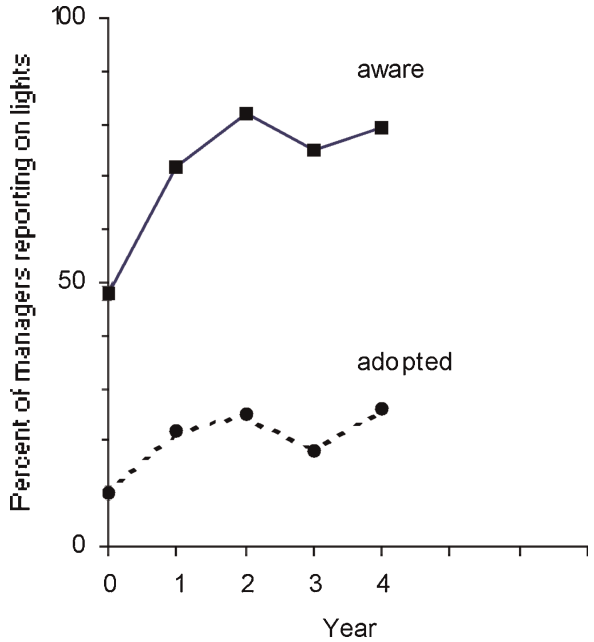

FIGURE 1. Barn lights awareness and adoption reported by Northeast Wisconsin managers.

TABLE II. Logistic Regression Analyses for Adoption and Awareness of Three Practices by Northeast Wisconsin Dairy Farmers

	Barn lights		Silage bags		Calf feed mixing sites	
Variable	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Adoption						
Intervention years	5.58[a]	3.39–9.17	2.94[a]	1.84–4.70	2.15	0.75–6.17
Manager age	0.97	0.91–1.04	0.97[d]	0.95–1.00	0.96	0.90–1.04
Manager sex	0.56	0.08–3.77	1.32	0.72–2.41	n/a[e]	n/a[e]
Manager years in dairy farming	1.01	0.95–1.08	1.01	0.98–1.03	1.02	0.95–1.10
Manager education	1.23[b]	0.99–1.53	1.03	0.94–1.13	1.03	0.83–1.28
Operation gross sales	3.00[a]	2.01–4.48	1.20[c]	1.05–1.36	1.86[a]	1.42–2.44
% of operation assets debt free	0.99[b]	0.97–1.00	0.99[c]	0.99–1.00	0.99	0.98–1.01
Operation herd size	0.99[c]	0.99–1.00	1.00	0.99–1.00	1.00	0.99–1.003
Awareness						
Intervention years	2.78[a]	2.07–3.74	1.60	0.79–3.23	1.60[a]	1.22–2.10
Manager age	0.97[c]	0.95–0.99	1.01	0.96–1.07	0.97[a]	0.95–0.99
Manager sex	0.63[b]	0.38–1.05	1.53	0.36–6.52	0.70	0.43–1.14
Manager years in dairy farming	1.01	0.99–1.03	0.99	0.95–1.04	1.02[d]	1.00–1.04
Manager education	1.19[a]	1.10–1.29	1.11	0.91–1.36	1.10[c]	1.03–1.18
Operation gross sales	1.28[a]	1.15–1.42	1.44[c]	1.11–1.86	1.30[a]	1.17–1.44
% of operation assets debt free	1.00	0.99–1.00	0.99	0.98–1.00	1.00[b]	0.99–1.00
Operation herd size	1.00[b]	0.99–1.00	1.00	0.99–1.00	1.00	0.99–1.00

CI, confidence interval.
[a] $P \leq 0.001$.
[b] $P \leq 0.10$.
[c] $P \leq 0.01$.
[d] $P \leq 0.05$.
[e] Too few observations, female = 0 predicts failure perfectly. Female dropped and 30 observations not used.

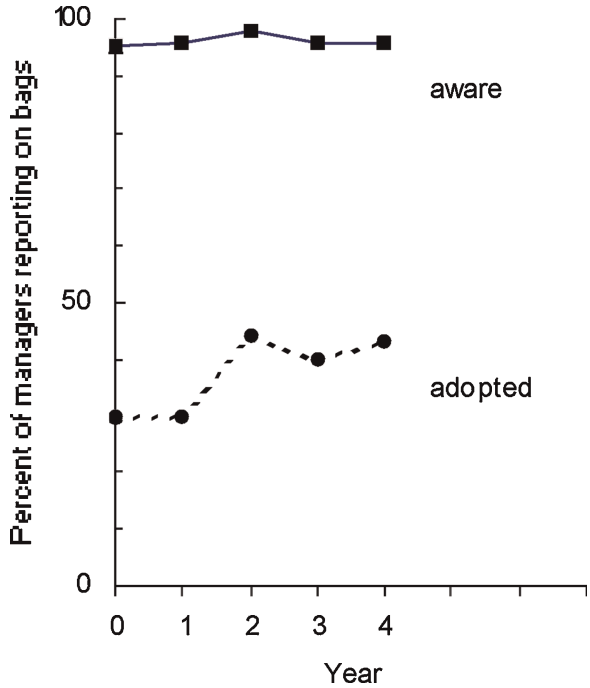

FIGURE 2. Silage bags awareness and adoption reported by Northeast Wisconsin managers.

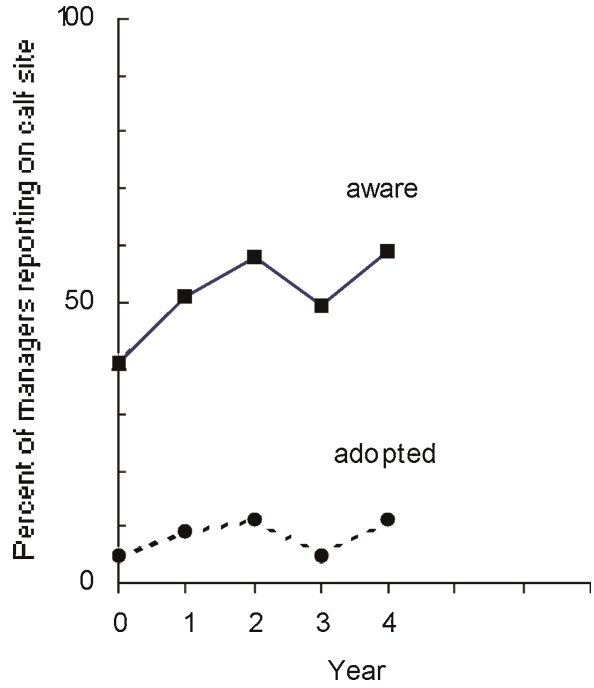

FIGURE 3. Calf feed sites awareness and adoption reported by Northeast Wisconsin managers.

practices after the fourth intervention year: barn lights (OR = 2.78, CI = 2.07–3.74) and calf feeding sites (OR = 1.60, CI = 1.22–2.10) but not silage bags (Table II). When other variables were held constant, higher operation gross sales was associated with increased awareness for all three practices. For both barn lights and calf sites, increased awareness was associated with younger manager ages and greater manager education. More manager years in dairy farming was associated with increased awareness of the calf feeding sites (Figs. 1–3 and Table II).

Compared to the Maryland farmers, significantly more Wisconsin farmers were aware of barn lights (79% vs. 65%, $P < 0.008$) after the fourth year of the intervention.

DISCUSSION

Did Managers Report Getting More Information?

Baseline reports compared to results collected after the fourth intervention year provided evidence that Wisconsin farmers did get significantly more information about all three practices from equipment dealers and about both barn lights and calf sites from public events, and about both barn lights and silage bags from other farmers. For barn lights, they also got more information from private consultants and electrical suppliers. These findings suggest that our intervention used information channels effectively, if somewhat unevenly, to reach farmers. The reliance on other farmers and public events largely confirms earlier research about which sources of production practice information were most often used by Wisconsin dairy farmers although the absence of print media as an important source was unusual [Fett and Mundy, 1990; Smith, 1995; Chapman et al., 2009a]. To our knowledge, previous research has not used nor demonstrated that farm consultants or electrical suppliers can act as sources of new production method information.

The reports from Wisconsin dairy managers about getting information from university Extension decreased over the 4-year intervention for all three practices (barn lights: 24% vs. 18%, silage bags: 19% vs. 8%, calf feeding sites: 13% vs. 4%). On the other hand, previous research has shown that users of information provided by university Extension often failed to attribute it correctly because the role of agents and specialists in information disseminated through public events, print media, and other sources often goes unrecognized [ECOP, 2002; Kalambokidis, 2004; Hoag, 2005]. In our experience, our work with university Extension agents and specialists was useful and often vital to our efforts to socially market the three practices in this article. University Extension personnel were involved in organizing and presenting at most of the dairy manager public events over the 4 years. Extension was also often the bridge to information dissemination through dairy print publications, other farmers, and resource people. Previous research suggests that university Extension ‘‘has its greatest impact in the early stages of dissemination of a new technology. As more farmers become aware of the new technology, the

impact of extension diminishes'' [Anderson and Feder, 2004, p. 42].

As noted earlier, we considered Maryland farmers a ''partially exposed'' comparison group because we suspected that they were as likely as Wisconsin farmers to read many of the same nationally distributed dairy trade publications and other print media where articles assisted by our intervention appeared about the three practices. The questionnaire data provided evidence to support this idea. The percent of Wisconsin versus Maryland dairy farmers who reported getting information from print media about each one of the three practices after the fourth year of the intervention was not significantly different. However, more Wisconsin than Maryland farmers reported getting both barn lights and bag silo information from public events and, for barn lights alone, from extension agents and electrical suppliers and for silage bags alone from other farmers and veterinarians. This suggests that Maryland dairy farmers were indeed exposed to the print media component of our intervention but not to the public events, university Extension agents, electrical suppliers, and other geographically specific intervention components delivered in Wisconsin.

Did Managers Report More Awareness and Adoption?

The most important goal of our intervention was to increase adoption of the three safer practices. Within the Wisconsin treatment group, the logistic regression analyses showed that results after the four intervention years were associated with increased adoption of two practices (barn lights and silage bags) compared to the Wisconsin baseline and with increased awareness of two (barn lights and calf feed sites). This suggests that our intervention was successful. Silage bag awareness was already widespread in Wisconsin prior to our intervention (i.e., 95%), so our intervention had little room to improve it. We had selected silage bags because relatively few dairy managers had adopted them even though nearly all were aware of them and because, once adopted, they could contribute to important reductions in fall, suffocation, and entanglement hazard exposures.

On the other hand, there were no important differences between results after years 2 and 4 of the intervention for either adoption or awareness of any of the three practices. This suggests that our intervention failed to advance and simply maintained its gains from the first 2 years. We are uncertain why both adoption and awareness gains appeared to plateau after the second intervention year but we can offer some ideas. During the last 2 years we may have approached the upper bound of operations for which our three interventions were realistic options. Those managers who could easily adopt may have done so in the first 2 years. In the last 2 years there may have been little change because the remaining managers were resistant. Milk price volatility may have been another factor discouraging managers from investing in production practice improvements in years 3 and 4. Annual average milk prices received by farmers decreased over the 4 years, dropping 14% between intervention years 2 and 3 but then recovering somewhat by the end of year 4 (i.e., years 1–4 = \$15.50, \$14.35, \$12.31, and \$14.97) [USDA, 2010]. Researchers studying the adoption of more sustainable agricultural practices have also noted that farm characteristics and other factors can slow or speed adoption at different points in time along the diffusion path [Fuglie and Kascak, 2001].

As expected, we found significant associations between younger Wisconsin manager ages and increased awareness of barn lights and calf sites and increased adoption of silage bags that were consistent with previous research on the adoption of agricultural innovations [Feder and Umali, 1993; Wejnert, 2002; Rogers, 2003]. Similarly, we also found significant associations between greater manager education and increased awareness (for barn lights and calf feed sites) for which there were precedents in other agricultural innovation research [Feder and Umali, 1993; Wejnert, 2002; Rogers, 2003]. The association that was most consistently significant was between higher operation gross sales and increased adoption and awareness (both were significant for adoption and awareness of all three practices in Wisconsin). Since gross sales can be considered to be a proxy for operation size, this finding was also consistent with other previous research on agricultural innovations [Feder and Umali, 1993; Wejnert, 2002; Rogers, 2003].

Our results also showed few awareness or adoption differences between the Wisconsin managers and the comparison group of Maryland managers after intervention year 4. We did find a significant difference favoring awareness of barn lights among Wisconsin over Maryland managers but there were no significant differences for the other awareness and adoption comparisons. As described above in the discussion about ''Did managers get more information,'' we considered the Maryland comparison samples to be ''partially exposed controls.'' They had access to the same national print publications and to the internet resources we used to disseminate information about the three practices. There was no way for us to completely isolate the Maryland dairy managers from our intervention and, at the same time, emphasize the dissemination of information through the sources Wisconsin managers said they used and trusted. Certain other factors may have contributed to these findings. Our study's statistical power to detect small differences between the Wisconsin and Maryland managers was less than optimal. First, budget limitations meant that the Maryland group size that we mailed to each year was smaller than the Wisconsin group. Second, the Maryland manager response rate was lower than that for Wisconsin managers each year. Combined, these two factors worked to reduce our

ability to detect small differences between the groups on outcomes such as adoption and awareness.

After the intervention, the reports from our dairy farm manager sample suggested that safer barn lighting was likely to be in use on about one in four Northeast Wisconsin dairy farms and safer silage bags were likely to be in use on about four of nine. More widespread use of safer production practices is likely to be associated with reduced numbers of exposures and exposures of shorter duration to injury hazards that could contribute to reductions in specific types of injuries. Between 1992 and 2003, there were a total of 16 Wisconsin farmer deaths (and an undetermined number of nonfatal injuries) attributed to falls, suffocations, and silo unloader machinery entanglements from tower silos [Josefsson et al., 2001; Skjolaas et al., 2005]. Conceivably, if all Wisconsin farmers using tower silos or other methods of silage storage replaced them by adopting silage bags, few or no future deaths or other injuries would occur that were attributable to these tower silos hazards. Similarly, if all Wisconsin farmers adopted barn lights, then fatal and nonfatal injuries due to falls on the same level could be reduced.

Our study questionnaire collected data from managers about the numbers and types of injuries requiring medical care on their operations in the last year (Table I). Unfortunately, the number of dairy operations in our sample groups each year was too small to reveal differences related to the specific injury risk factors that could be reduced by the three practices we promoted. Currently, the surveillance of both fatal and nonfatal injuries in the dairy industry and in all of production agriculture in the US is much less comprehensive and accurate than in other industries [McCurdy and Carroll, 2000; Hard et al., 2002]. Improvements in agricultural injury surveillance, including better recording of nonfatal injuries and greater detail about causal factors that contribute to nonfatal and fatal injuries on both large and small farms, may allow research to link interventions like ours with specific measures of injury reduction.

Strengths and Limitations

Our research lacked some of the attributes that are desired for optimal workplace intervention evaluation research (i.e., random assignment to treatment groups, control comparison groups confidently isolated from all treatment aspects, verification of self-reported data, and links with objective measures of injury reduction with enough statistical power for attribution to the intervention) [Robson et al., 2001; Rautianen et al., 2008]. However, our study did incorporate other desirable attributes, including a theoretical model, prospective community-based probability samples, long-term follow-up, relatively large-sized intervention and evaluation subject groups, and some injury reporting. Because our subjects were not randomly assigned to treatment, our evidence was not causal but associational and so the gains we observed in practice adoption and awareness may be attributable, wholly or in part, to ongoing industry trends or other influences, instead of our intervention. More research to follow these gains in Wisconsin and to compare them with results from other samples of dairy farmers who were better isolated from the intervention could better separate any effect of time from the effect of the intervention.

Nationwide, most of the 71,510 dairy operations in the US in 2007 [USDA, 2009] were exempted by federal budget riders from enforcement of governmental occupational safety regulations [Murphy, 1992; Kelsey, 1994; McCurdy and Carroll, 2000]. Dairy farm managers may be placed at a disadvantage due to unsafe conditions and injuries that interfere with production. Our research suggests that promoting safer work with information dissemination interventions that emphasize the greater profitability of safer work practices may be a viable interim supplement to more comprehensive occupational safety regulation and enforcement in the dairy industry.

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REFERENCES

Ag Source Cooperative Service. 1996–2001. List of dairy herd improvement program members. Madison, WI: Ag Source Cooperative Service.

Ahearn M, Yee J, Ball E, Nehring R. 1998. Agricultural productivity in the US. Agricultural information bulletin no. 740. Washington, DC: USDA Economic Research Service.

Ahonen E, Venalainen J, Kononen U, Klen T. 1990. The physical strain of dairy farming. Ergonomics 33:1549–1555.

Anderson JR, Feder G. 2004. Agricultural extension: Good intentions and hard realities. World Bank Res Obs 19:41–60.

Bentley T, Tappin D, Moore D, Legg S, Ashby L, Parker R. 2005. Investigating slips, trips and falls in the New Zealand dairy farming sector. Ergonomics 48(8):1008–1019.

Bhattacharya A. Ergonomics of Task Performance on Slippery Surfaces. Final Report on Project R01 OH030079. Cincinnati OH: US NIOSH, 1998.

Chapman LJ, Josefsson KG, Taveira AH, Karsh B, Hard D. 2003. Evaluation of an occupational injury intervention among Wisconsin dairy farmers. J Agric Saf Health 9(3):197–209.

Chapman LJ, Newenhouse AC, Meyer RH, Taveira AD, Karsh B, Ehlers J, Palermo T. 2004. Evaluation of an intervention to reduce musculoskeletal hazards among fresh market vegetable growers. Appl Ergon 35:57–66.

Chapman LJ, Newenhouse AC, Karsh BT, Taveira AD. 2009a. The use and value of information systems as evaluated by dairy and specialty crop farm mangers. J Agromedicine 14(1):1–12.

Chapman LJ, Karsh B, Taviera A, Josefsson KG, Brunette C, Pereira KM. 2009b. An intervention to increase adoption of safer dairy farming practices. Public Health Reps 124 (suppl 1):125–133.

Chastain JP, Hiatt RS. 1994. On-site investigation of indoor lighting systems for dairy facilities. ASAE paper number 945507. Presented at the winter meeting of the American Society of Agricultural Engineers. Available from ASAE, St. Joseph, MI.

Dahl GE, Buchanan BA, Tucker HA. 2000. Photoperiodic effects on dairy cattle: A review. J Dairy Sci 83:885–893.

Davies JC, Kemp GJ, Stevens G, Frostick SP, Manning DP. 2001. Bifocal/varifocal spectacles, lighting and missed-step accidents. Saf Sci 38:211–226.

Davis KG, Kotowski SE. 2007. Understanding the ergonomic risk for musculoskeletal disorders in the United States agricultural sector. Am J Ind Med 50:501–511.

Dillman DA. 2000. Mail and internet surveys: The tailored design method, 2nd edition. New York: Wiley & Sons.

Dillman DA. 2006. Why choice of survey mode makes a difference. Public Health Rep 721:11–13. PMID 16416693.

Douphrate DI, Rosecrance JC, Stallones L, Reynolds SJ, Gilkey DP. 2009. Livestock handling injuries in agriculture: An analysis of Colorado workers' compensation data. Am J Ind Med 52:391–407.

Extension Committee on Organization and Policy (ECOP). 2002. The extension system: A vision for the 21st century. Washington, DC: National Association of State Universities and Land-Grant Colleges.

Feder G, Umali DL. 1993. The adoption of agricultural innovations: A review. Technol Forecasting Soc Change 43:215–239.

Fett J, Mundy P. Disseminating annual crop practice recommendations via supplements in weekly agricultural newspapers. Paper presented at the Agricultural Communicators in Education annual convention, Minneapolis, MN, July 15–18, 1990. Reprints c/o J Fett, University of Wisconsin Agricultural Journalism Department, 440 Henry Mall, Madison, WI 53706, USA.

Fuglie KO, Kascak CA. 2001. Adoption and diffusion of natural-resource-conserving agricultural technology. Rev Agric Econ 23(2): 386–403.

Gerberich SG, Gibson RW, Gunderson PD, French LR, Martin F, True JA, Shutske J, Carr WP, Stasch B. 1993. Regional Rural Injury Study (RRIS): A five state population based effort funded by the Centers for Disease Control, 1989–1992. St. Paul, MN: University of Minnesota School of Public Health.

Hard DL, Myers JR, Gerberich SG. 2002. Traumatic injuries in agriculture. J Agric Saf Health 6(1):51–65.

Hoag D. Economic principles for saving the cooperative extension service. Presidential Address to the Western Agricultural Economics Association. 2005. http://agecon.uwyo.edu/waea/2005AssnMtg/2005PresidentialAddressWAEA.pdf. Accessed June 11, 2010.

Josefsson KG, Miquelon M, Chapman LJ. 1999a. Work efficiency tip sheet on long day lighting in dairy barns. Madison, WI: University of Wisconsin, Biological Systems Engineering Department, http://bse.wisc.edu/hfhp/.

Josefsson KG, Miquelon M, Chapman LJ. 1999b. Work efficiency tip sheet on using silage bags. Madison, WI: University of Wisconsin, Biological Systems Engineering Department, http://bse.wisc.edu/hfhp/.

Josefsson KG, Miquelon M, Chapman LJ. 1999c. Work efficiency tip sheet on liquid feed mixing facilities for dairy calves. Madison, WI: University of Wisconsin, Biological Systems Engineering Department, http://bse.wisc.edu/hfhp/.

Josefsson KG, Chapman LJ, Taveira A, Hard DL. 2001. A hazard analysis of three silage storage methods for dairy cattle. Hum Ecol Risk Assess 7(7):1895–1908.

Kalambokidis L. 2004. Identifying the public value in extension programs. J Ext 42(2): Available at: http://www.joe.org/joe/2004april/a1/shtml

Kelsey TW. 1994. The agrarian myth and policy responses to farm safety. Am J Public Health 84:1171–1177.

Kolstrup C, Stal M, Pinzke S, Lundqvist P. 2006. Ache, pain, and discomfort: The reward for working with many cows and sows? J Agromed 11(2):45–55.

Lundqvist P. 1996. Evaluation of the improvements in working conditions on farms funded by the Swedish working life fund. J Agric Saf Health 2(4):191–196.

McCurdy SA, Carroll DJ. 2000. Agricultural injury. Am J Ind Med 38:463–480.

Menard S. 2002. Applied logistic regression analysis. Thousand Oaks, CA: Sage Publications.

Murphy D. 1992. Safety and health for production agriculture. St. Joseph, MI: American Society of Agricultural Engineers.

Myers JR. 1998. Injuries among farm workers in the United States, 1994. DHHS (NIOSH) Pub. No. 98–153. Cincinnati, OH: National Institute for Occupational Safety and Health.

Myers JR, Hard DL. 1995. Work-related fatalities in the agricultural production and services sectors, 1980–1989. Am J Ind Med 26:51–63.

NIOSH. 1998. National Institute for Occupational Safety and Health. Surveillance for nonfatal occupational injuries treated in hospital emergency departments—US, 1996. MMWR Morb Mortal Wkly Rep 47(15):302–306.

Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. 2008. Musculoskeletal symptoms of the neck and upper extremities among Iowa dairy farmers. Am J Ind Med 51:443–451.

Perkio-Makela M, Hentila H. 2005. Physical work strain of dairy farming in loose housing barns. Int J Ind Erg 35:57–65.

Peters RR. 1994. Photoperiod and management of dairy cows: A practical review. In: Bucklin R, editor. Dairy systems for the 21st century. Proceedings of the Third International Dairy Housing Conference. St Joseph, MI: American Society of Agricultural Engineers.

Pinske S. 2003. Changes in working conditions and health among dairy farmers in Southern Sweden: A 14 year follow-up. Ann Agric Environ Med 10:185–195.

Pratt DS, Marvel LH, Darrow D, Stallones L, May JJ, Jenkins P. 1992. Dangers of dairy farming: The injury experience of 600 workers followed for two years. Am J Ind Med 21:637–650.

Rautiainen RH, Lehtola MM, Day LM, Schonstein E, Suutarinen J, Salminen S, Verbeek J. 2008. Interventions for preventing agricultural injuries in the workplace. Cochrane DB Syst Rev February (Issue 1). Art. No.: CD006398.

Robson LS, Shannon HS, Goldenhar LM, Hale AR. 2001. Guide to evaluating the effectiveness of strategies for preventing work injuries.

DHSS(NIOSH) publication no. 2001–2119. Cincinnati, OH: National Institute for Occupational Safety and Health.

Rogers E. 2003. Diffusion of innovations, 5th edition. New York: Free Press.

Salant P, Dillman DA. 1994. How to conduct your own survey. New York: Wiley & Sons.

Skjolaas CA, Schuler R, Kirschner H, Chapman LJ. 2005. 1992–2003 Wisconsin farm-related fatalities. Madison: University of Wisconsin Biological Systems Engineering. Department's Center for Agricultural Safety and Health, www.wiscash.uwex.edu/Documents/PDFfiles/FatalitiesReports/fatal04.pdf.

Smith T. 1995. Wisconsin dairy industry needs assessment. Madison, WI: University of Wisconsin Center for Dairy Profitability.

SPSS. 1996. Statistical package for the social sciences. New York: McGraw Hill.

State of Maryland Department of Agriculture. 1998. Brucellosis ring test list. 1998–1999 to 2000–2001.

Treno AJ, Breed L, Holder HD, Roeper P, Thomas BA, Gruenewald PJ. 1996. Evaluation of media advocacy efforts within a community trail to reduce alcohol-involved injury. Eval Rev 20:404–423.

US Department of Agriculture. 2009. National Agricultural Statistics Service. Table 8–4. Milk cows: Number of operations, 2006–2007, and inventory, January 1, 2007–2008, by selected States and United States, http://www.nass.usda.gov/Publications/Ag_Statistics/2008/Chap08.pdfUS. Accessed August 3, 2009.

US Department of Agriculture. 2010. National Agricultural Statistics Service Data. Prices Received by farmers, all milk. 1996–2004. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1207. Accessed June 4, 2010.

Wejnert B. 2002. Integrating models of diffusion of innovations: A conceptual framework. Ann Rev Sociol 28:297–326.

Wisconsin Department of Agriculture Trade, and Consumer Protection. 1997–2001. Brucellosis ring test list. Madison, WI: Wisconsin Department of Agriculture Trade, and Consumer Protection.