ORIGINAL ARTICLE

Escherichia coli O157:H7 – Discerning Facts from Fiction: An Integrated Research and Extension Project for Multiple Audiences

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Impacts

- Myths about risk and pre-harvest control of *Escherichia coli* serotype O157:H7 continue to be spread through the Internet and other media.
- The complexity of *Escherichia coli* serotype O157:H7 epidemiology and the efficacy of some pre-harvest measures to reduce shedding can be effectively communicated to a variety of audiences.
- New methods of needs assessment using Internet environmental scanning and message dissemination can identify perpetuated myths and quickly address them.

Keywords:
Escherichia coli; cattle; extension; education; pre-harvest; Shiga-toxin-producing *Escherichia coli*

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Summary

The O157:H7 (*Ec*O157) epidemiology of Shiga-toxin-producing *Escherichia coli* (STEC) in cattle is complex, and myths about pre-harvest control are perpetuated. The objectives of this project were to identify perpetuated misinformation and inform four audiences about evidence-based risks and pre-harvest control of *Ec*O157 by addressing: (i) *Ec*O157 epidemiology and pre-harvest control; (ii) how food safety policy is created; and (iii) how to present accurate information about *Ec*O157. An environmental scan using a daily Internet search helped identify themes for education. A literature review of pre-harvest control measures contributed to the development of educational materials (fact sheets, website, web presentations and conferences). Conference 1 was a webinar with 315 registrants, 10 countries including 41 US states and four Canadian provinces. Most participants felt confident in using their new knowledge, more than half felt confident enough to answer *Ec*O157 questions from the public and many would recommend the recorded version of the webinar to colleagues. Conference 2 was live in the Washington, DC, area with most participants employed by the US government. All agreed that they better understood pre-harvest control, how food safety policy was made, and were confident they could create an effective message about STEC pre-harvest control. Videos were posted and received 348 Internet visitors within 2 months. Conference 3 was a webinar with a live audience and Twitter feeds, targeting people who give nutrition advice. Almost all ranked the programme good to excellent and relevant to their work. About 25% indicated that they would share: 'grass-fed beef is not safer than grain-fed', 25% would share information on effectiveness of cattle vaccines, and 14% would share information on message mapping. Across all conferences, major changes in knowledge included the following: there is no additional risk of *Ec*O157 shedding from grain-fed versus grass-fed cattle, pre-harvest vaccination is efficacious, and production systems (pasture versus confinement) do not affect *Ec*O157 shedding rates.

Introduction

Shiga-toxin-producing *Escherichia coli* (STEC) are important public health pathogens associated with diarrhoea, bloody diarrhoea and haemolytic uraemic syndrome. The most important STEC is serotype O157:H7 (*Ec*O157) and is defined as a zero tolerance food adulterant. Six other STEC serovars including O26, O45, O103, O111 and O145 (non-O157 STEC) are also considered food adulterants. The epidemiology of *Ec*O157 is well studied, and non-O157 STEC are assumed to have similar epidemiological characteristics.

This foodborne bacterium and its association with the cattle reservoir, foods of bovine origin and environmental contamination leading to human exposure have had large impacts on the sustainability of the US livestock industry, costing billions of dollars (Kay, 2003) from reduced consumer demand, product recalls and ultimately the costs of human morbidity and mortality. The direct and indirect human health costs alone are estimated at >$400 million annually (Frenzen et al., 2005). On the positive end, *Ec*O157 disease incidence in humans has levelled off after previous declines (USPHS: Centers for Disease Control and Prevention, 2012a,b). However, despite promising on-farm interventions to reduce *Ec*O157 shedding in cattle, large meat recalls continue to affect the beef industry and the consumer.

The reservoir of *Ec*O157 is complex and incompletely defined. However, there is general agreement that ruminant animals constitute an important facet of this reservoir. This is true for both foodborne infections involving ruminant origin products including beef, lamb and unpasteurized milk, and infections resulting from direct contact with animals (Rangel et al., 2005; Besser et al., 2011; Ferens and Hovde, 2011). *Ec*O157 is transmitted to humans by ingestion of contaminated foodstuffs or water or by direct contact with infected cattle or other hosts.

The past two decades of research have resulted in an extensive understanding of the biology of *Ec*O157 in cattle. This research has identified promising on-farm and processing plant interventions that reduce farm and cattle prevalence and shedding of *Ec*O157 as well as processing plant contamination. These interventions intend to reduce food contamination and environmental human exposures to *Ec*O157 (LeJeune and Wetzel, 2007; Callaway et al., 2009). While this research and other food safety research is the basis of a science-based strategy for improving the safety of the food supply (Oliver et al., 2009), translation of that science into public knowledge has been difficult.

Although there have been and continue to be conferences and educational materials that present and update the state of knowledge about *Ec*O157 and interventions to reduce meat contamination, they have tended to be directed to specific audiences (e.g., the meat industry or the scientific community). For example, recent conferences have focused on researchers with some industry and government attendees (http://www.stecbeefsafety.org/annual-conference).

Relatively little has been done to bring diverse stakeholders, including public health, together or provide multitiered approaches to educate broader audiences involved with this issue. As a consequence, information available and disseminated by those outside the scientific community and industries may not reflect the best available scientific information. Following many new *Ec*O157 outbreak-associated meat recalls, the media often cite an association between cattle fed a grain diet and *Ec*O157 shedding even though extensive research has failed to support this hypothesis (Hancock et al., 2001; Callaway et al., 2009; Fink et al., 2013; Sheng et al., 2013). *Ec*O157 has repeatedly been demonstrated to be carried by range cattle (and other or other forage-fed cattle) often at similar prevalence as in grain-fed cattle (Fegan et al., 2004; Renter et al., 2004) As an example, a *New York Times* editorial 'Leafy Green Sewage' on September 21, 2006, stated as follows: '[*E. coli* O157:H7 is] *not found in the intestinal tracts of cattle raised on their natural diet of grass, hay and other fibrous forage. No, O157 thrives in a new – that is, recent in the history of animal diets – biological niche: the unnaturally acidic stomachs of beef and dairy cattle fed on grain, the typical ration on most industrial farms*'. If the science community cannot communicate the best information on food safety and *Ec*O157 control, misinformation will likely be perpetuated.

Risk communication is a relatively new discipline and has become integral to public health practice (Feimuth et al., 2000). Effectively communicating risks involves the use of specific techniques to better inform the public and other audiences (Glik, 2007). One approach to risk communication is the 'segmented' communication approach (Verbeke et al., 2007). This requires that the population be segmented according to their information needs. In addition, when communicating risks to individuals who will be communicating that information to others, having them internalize the new information by writing their own risk communication messages for their specific audiences would be one way for them to effectively learn the new material (D. Moore, Personal communication, 2010). The best practices for risk communication include 'collaborating and coordinating with credible sources' (Seeger, 2006), and the scientific community should be one of those credible sources for the risk communication practitioners.

The purpose of this project was to educate and inform four target audiences about current information from evidence-based studies describing *Ec*O157 risks and potential for better pre-harvest control. These audiences included

practicing cattle veterinarians along with public health and regulatory practitioners, policy-makers within regulatory and public health, individuals who provide diet or nutrition advice and science-writers who may report on food safety issues. The objectives were to (i) identify common misstatements about pre-harvest EcO157 control that could inform a curriculum; (ii) have audiences able to recognize the complexity of *Ec*O157 epidemiology; (iii) have audiences able to discuss how food safety policy is created and enforced; and (iv) develop audience skills to create messages to replace misstatements with current evidence-based information and internalize their new knowledge.

Materials and Methods

A multitiered approach to outreach for a variety of audiences was developed for this programme with a series of planned outputs. The outreach programme content was built on two pillars: defining educational needs and identifying the research evidence to support programme development to address those needs. The evaluation tool and project were provided exempt status for human subjects by the WSU Institutional Review Board.

Educational needs assessment via an environmental scan

At the beginning of the project (February 9, 2011), the term '*E. coli* cattle' was put into 'Google Alerts' (http://www.google.com/alerts), a search query system that continuously monitors Internet traffic on a topic and forwards traffic summaries as a daily email update. Each alert instance was scanned for mention of pre-harvest control of Shiga-toxin producing *E. coli* (STEC) bacteria. Qualitatively, a list of themes emerged regarding cattle pre-harvest concerns, and control measures mentioned were recorded into a computerized spreadsheet (Excel; Microsoft Corp., Redmond, WA, USA) and coded by theme. Major themes included cattle production system, cattle diets and pre-harvest control measures. These themes were summarized and served to define some of the educational needs for the audiences.

Research evidence

A comprehensive literature review of pre-harvest measures to control *Ec*O157 was used to develop the knowledge base for addressing themes from the educational needs assessment. The review broadly addressed three topics: general knowledge of *Ec*O157 on farms, diet impacts on *Ec*O157 and on-farm interventions to reduce *Ec*O157 shedding. The results from these evaluations were summarized and posted on a project-specific website (http://extension.wsu.edu/vetextension/ec/Pages/Factsheets.aspx). Fact sheets based on these data were also developed.

Conference objectives, audience and programme

Three conference programmes were designed and implemented targeting three distinct audiences. The first conference was a webinar for public health, food safety and practicing veterinarians. This conference was titled '*E. coli Update – Current perspectives on cattle, produce, and human health*', and its objectives were to (i) engage a diverse audience with current research and issues surrounding *Ec*O157, (ii) develop connections and relationships for a year-long discussion on *Ec*O157 policy culminating in a face-to-face conference on policy, (iii) have participants understand *Ec*O157 epidemiology, (iv) have participants identify evidence-supported means for reducing *Ec*O157 shedding by cattle, (v) have participants describe the pathogenesis of *Ec*O157 infections in people and (vi) have participants describe and reconcile the controversy surrounding the label 'adulterant' in meat. This webinar was marketed to the American College of Veterinary Preventive Medicine diplomats, USDA:FSIS Public Health Veterinarians through their professional development office, veterinarians within the Federal Centres for Disease Control and Prevention, the Association of State and Territorial Public Health Veterinarians, the American Association of Extension Veterinarians and the American Association of Bovine Practitioners through personal contacts, organization email lists, colleges of veterinary medicine and requests to forward email announcements to colleagues. Continuing veterinary medical education (CVME) credit for attending the conference was offered through the College of Veterinary Medicine at Washington State University with a requirement being completion of an online programme evaluation. The webinar was designed as a 3.5-h conference with a moderator, four subject matter speakers and a speaker panel. Questions from the webinar audience to the speaker panel were solicited through an online chat room, screened by the moderator and given to the panel. At the end of the webinar, participants were encouraged to visit a survey site (SurveyMonkey®, http://www.surveymonkey.com) to complete a course evaluation. The presentations were videotaped, and all videos were edited and placed on the project website (http://extension.wsu.edu/vetextension/ec/Pages/default.aspx) as enduring materials.

The second conference '*Pre-Harvest Control of STECs in Cattle*' was designed as a face-to-face conference for policy makers and regulatory stakeholders in the Washington, D.C., area. The objectives were to (i) engage regulatory personnel and scientists in a discussion on STEC control, (ii) have participants better understand *Ec*O157 epidemiology (risk factors and interventions for), (iii) have participants gain a better grasp on how food safety

policy is created and enforced, (iv) have participants experience creating messages to communicate *Ec*O157 epidemiology and specifically current information about *Ec*O157 pre-harvest control strategies. Invitations to this conference were extended to those who participated in the first webinar as well as regulatory personnel within USDA and FDA, and national meat, cattle and veterinary organizations. This full-day conference included project researchers as speakers as well as regulatory experts to provide overviews of policy development within their agencies. The programme culminated with group work on developing messages about programme content and the delivery of those messages. An audience response system (Turning Point; Turning Technologies, Youngstown, OH, USA) was used to evaluate before and after conference knowledge. A paper programme evaluation was also provided. Continuing education credit was provided. Enduring materials included web-posted, edited videos of the presentations.

The third conference was held as a webinar with a live audience that targeted individuals providing human nutrition and diet advice. The objectives of '*Beef Food Safety: Are you giving the right message?*' were to (i) have participants better understand pre-harvest STEC control, (ii) have participants better understand how cattle feeds and production systems affect STEC shedding and (iii) improve participant confidence to create an effective message about beef food safety. Marketing of this conference was done through Extension and university information resources as well as to previous programme participants. To reach individuals who provided nutritional advice to consumers, the programme was marketed through the School Nutrition Association, Academy of Nutrition and Dietetics, FDA, International Food Information Council, State Dietetic Associations, Beef Check Off – State Association Nutritionists, Food Safety Academia Researchers and Food Scientists, and Washington State School Nutritionists. A programme evaluation was provided, and enduring materials included video presentations posted on the project website (http://extension.wsu.edu/vetextension/ec/Pages/default.aspx).

Web-based programme for science-writers

A web-based programme, '*Weighing the Evidence – A Guide to Thinking about E. coli O157:H7*', was developed in three modules and contained information on *Ec*O157 specifically designed for science-writers and the public using risk communication best practices (Vennette, 2006). The programmes were marketed to the National Association of Science Writers and American Medical Writers Association through their organizational coordinators.

Results

Environmental scan

Between February, 2011, and the first webinar in November, 2011, there were 144 'Google Alerts' that focused on pre-harvest STEC and cattle. Four major news stories were revealed by the scan that occurred during this time: (i) a press release about efficacy of cattle vaccination from a vaccine manufacturer, (ii) a large European outbreak of a non-O157 STEC, (iii) an outbreak of *Ec*O157 at the North Carolina State Fair and (iv) a press release on studies linking feeding of wet distillers grains to cattle resulting in higher *Ec*O157 shedding. Internet news and blogs following up on responding to these news stories included the following: stories on the 'other' STECs ($N = 27$) that USDA had labelled as food adulterants and that they required surveillance testing as for *Ec*O157 ($N = 6$), cattle vaccination as a way to reduce *Ec*O157 shedding ($N = 18$), and animals in public settings as sources of *Ec*O157 ($N = 10$). *Ec*O157 water contamination by cattle and wildlife ($N = 14$) was also discussed. Stories on pre-harvest control included cattle diet influences on *Ec*O157 ($N = 11$), cattle production practices' influence on shedding ($N = 16$) and antibiotic use influence on shedding ($N = 7$).

Review of pre-harvest control through cattle feeding and production management

A comprehensive review of pre-harvest control measures focused on cattle feeding and management practices was completed and posted as 'Published Literature on Dietary Components that Influence STEC O157 Fecal Shedding in Cattle' (http://extension.wsu.edu/vetextension/ec/Documents/LiteratureReviewTable_ExtensionPub-edited.pdf). Evidence from the literature review was organized around themes that emerged from the environmental scan to identify strengths and gaps in the information available through the media. Information gaps or 'myths' ('fact' differences between science and media publications) were identified and included the following: 'grass-fed beef is safer', 'industrial farming results in more *Ec*O157', 'antibiotic use in cattle leads to *Ec*O157 shedding' and 'local or organic food is safer with regard to *Ec*O157'. The information from the literature review led to a fact sheet for veterinarians, cattle producers, cattle nutritionists and others.

Conferences

Conference 1 (November, 2011)

There were 315 individuals who registered for the live webinar with at least 300 logged in. Eighty-one (27%) viewers completed the online evaluation, 54 of which requested a continuing education certificate. Within the following

45 days, another 23 people viewed the posted videos from the webinar. Webinar registrants were from 41 US states, the District of Columbia and three Canadian provinces (Figure 1). Outside of North America, participants from eight other countries (Australia, Germany, Greece, India, Israel, Italy, Singapore and Uruguay) registered and signed in. Of the 81 participants completing evaluations, 21% were in academia or were graduate students, 42% worked in government, 15% were practicing veterinarians, 11% were in industry, 4% were livestock producers and one participant worked in human medicine. Most of those completing the evaluation (57%) heard about the webinar through an organization newsletter or email list. About 30% of those completing the evaluation heard about the webinar from a colleague, 15% received a personal invitation from a speaker or organizer, and 10% either saw the webinar information in a media report or found it on the Internet.

Most participants completing the evaluation reported at least one technical difficulty with either choppy audio or video streaming issues. Despite this, participants completing the evaluation gave the webinar good reviews (Table 1). The subject matter, pace, duration and quality of speakers were satisfactory for the majority of those responding. Most felt confident in their new knowledge, more than half felt confident enough to answer *EcO157* questions from the public, and many would recommend the recorded version of the webinar to colleagues. A little more than half expressed some degree of interest in attending a live conference, with 62% of government-related attendees indicating an interest.

Participants were asked for what topics they would like more in-depth information. Most of those completing the evaluation (44%) wanted more in-depth information on the role of cattle in the epidemiology of *Ec*O157 (Table 2). Almost half indicated that they would like to see more on how to communicate *Ec*O157 information to consumers in a face-to-face setting. Just over 8% indicated that they had no previous webinar experience while 45% had participated in 1–6 webinars previously (Table 2). Because the subsequent conference was to target government and regulatory individuals, a breakdown of topic interest by job title was done. Those working in government were more likely to want more in-depth information on the role of cattle in the epidemiology of *Ec*O157 (59%) and how cattle feeding influences shedding (56%), and were particularly interested (73%) in how science can inform policy-making (Table 2.)

Conference 2 (November, 2012)

Fifty individuals registered for the day-long conference held in Rockville, MD. Of those, 44% were in

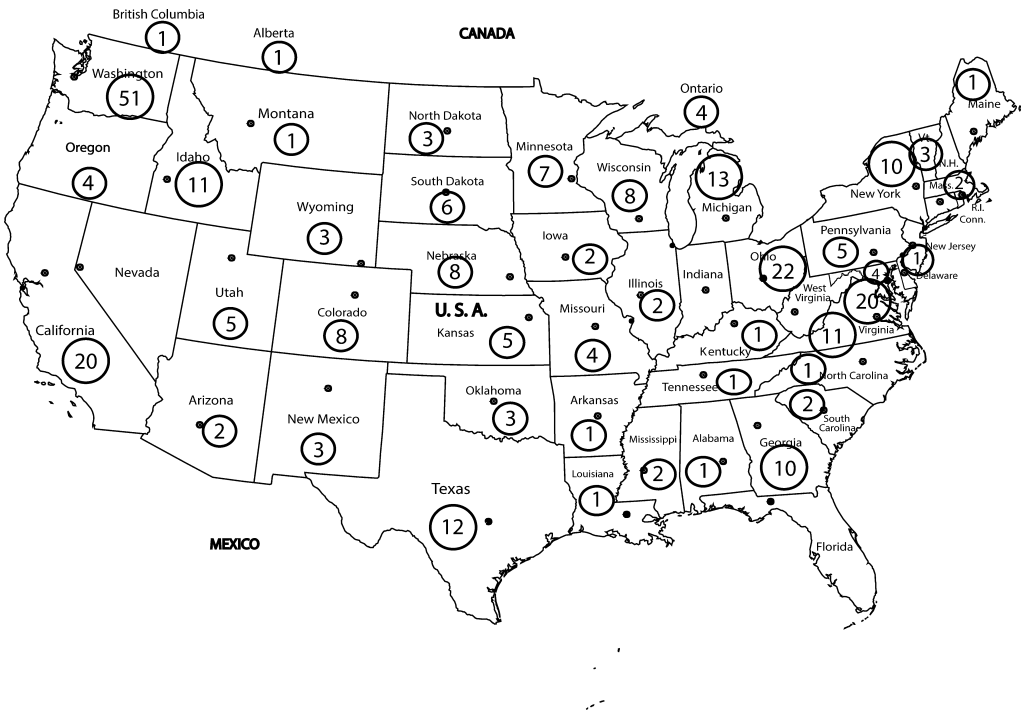

Fig. 1. Number of North American webinar registrants for the first pre-harvest *EcO157*:H7 conference, November, 2011, by state or province (N = 315).

Table 1. Responses to an online evaluation from a webinar on *Escherichia coli* O157:H7, results of webinar Conference 1

Evaluation question	Agree	Neutral	Disagree
The subject matter was presented effectively	76 (93.8%)	2 (2.5%)	3 (3.7%)
The pace of the webinar was satisfactory	73 (91.2%)	5 (6.2%)	3 (3.7%)
The duration of the webinar was sufficient for the material covered.	70 (86.4%)	7 (8.6%)	4 (4.9%)
The speakers were knowledgeable	78 (96.3%)	2 (2.5%)	1 (1.2%)
As a result of this webinar, I feel more confident in my knowledge about *E. coli* O157:H7	74 (91.4%)	6 (7.4%)	1 (1.2%)
As a result of this webinar, I would be confident to answer questions from the public about STEC *E. coli*	54 (66.7%)	20 (24.7%)	7 (8.6%)
This webinar met or exceeded my expectations	70 (86.4%)	7 (8.6%)	4 (4.9%)

	Too advanced	Too basic	Just right
The content of this webinar, based on your level of need was:	7 (8.7%)	12 (15%)	61 (76.3%)

	Very likely	Somewhat likely	Not likely
How likely would you be to recommend the recorded version of this webinar to a co-worker or colleague?	46 (58.2%)	29 (36.7%)	4 (5.1%)

	Not interested	Neutral	Somewhat interested	Very interested
What is your level of interest in attending a national conference in Fall 2012 to continue this discussion?	15 (18.7%)	13 (16.2%)	30 (37.5%)	22 (27.5%)

government positions, all but one federal, 26% were in industry, 10% held university positions and 20% did not specify. Following the programme's last formal presentation on message development, participants broke into five groups to discuss what they had learned, what barriers to pre-harvest control they thought important and to create a message associated with STEC for delivery to a specific audience. Pre-harvest control barriers listed by the groups included the following: cost of pre-harvest control and who should bear the cost, what the ultimate benefit of pre-harvest control was, public perception of STEC control, mistrust of vaccine efficacy information, reliance on post-harvest interventions for food safety, the limited set of effective options for pre-harvest control and the lack of *Ec*O157 clinical effect on animals. Messages developed by the breakout groups included the following: proper food handling by consumers, pre-harvest intervention (vaccine) effectiveness (three groups), that *Ec*O157 can be found in other products and the environment and that the cost of controlling *Ec*O157 should not be borne by the cattle producers alone.

Programme evaluation was facilitated by an audience response system (Turning Point; Turning Technologies) that gauged attendee's knowledge change as the conference progressed. The system was tested with the audience and used by 38 of 50 (79%) of the participants. Questions were asked before the speakers began and again at the end of the symposium. There was no change before and following the programme in the proportion (50% and 44% ($P = 0.41$), respectively) agreeing with the statement 'Food safety policy and regulations in the United States are primarily based on risk assessment of the foodborne hazard'. The same pattern of no significant change in agreement was observed for the statements that 'Feedlot owners will see a large return on their investment if they use a product to reduce shedding of *E. coli* O157:H7' (87% pre- and 69% post-programme disagreed) and 'food safety policy and interventions should be focused on post-harvest control measures' (62% pre- and 68.7% post-programme disagreed).

One of the conference goals was to address myths identified from the environmental scan. At the end of the conference, twice as many people (98%) disagreed with the statement 'Cattle that are grass-fed have lower rates of *E. coli* O157:H7 shedding than those that are fed high grain diets' compared to before the conference (45%; $P = 0.001$). Similarly, at the end of the conference, more people disagreed (71%) with the statement 'most *Ec*O157 shedding could be managed by changing the production system' compared to before the programme (51%; $P = 0.05$).

At the end of the programme, 43% of the participants completed the paper conference evaluation. All agreed or strongly agreed that they better understood the challenges of pre-harvest *Ec*O157 control, better understood how food safety policy was made and were confident they could

Table 2. Responses to an online survey about additional educational needs and experience with webinars after participation in Conference 1, an *Escherichia coli* O157 webinar. Responses are stratified by respondent job title

	Government *n* = 34	Human Medicine *n* = 1	Industry *n* = 9	Practicing Veterinarian *n* = 12	Producer *n* = 3	Total
Topic on which they would like more in-depth information						
Current perspectives on *E. coli* and human health	11	1	3	1	2	18
STECs and produce contamination	8	1	4	1	2	16
The role of cattle in the epidemiology of *E. coli* O157:H7	20	1	4	8	2	35
Does what we feed cattle have an effect on O157 shedding?	19		2	8	2	31
Is vaccination of cattle the answer?	16		5	9	1	31
	Government	Human medicine	Industry	Practicing veterinarian	Producer	Total
Besides this one, how many web-based trainings have you participated in?						
None	4	0	0	2	1	7
1 to 3	11	0	3	4	1	19
4 to 6	9	0	3	4	1	17
7 to 9	5	0	0	1	0	6
10 or more	5	1	3	1	0	10
What specific topics would you like to see in more depth at a face-to-face conference?						
The consequences of making other STEC *E. coli*'s as adulterants.	14	1	2	3	1	21
A review of the economics of *E. coli* O157:H7 pre-harvest control for beef cattle	18	1	6	8	1	34
A review of the economics of *E. coli* O157:H7 pre-harvest control for produce	11	1	3	2	1	18
How science can inform policy-making	25	1	4	4	1	35
Communicating *E. coli* risks to the consumer	19	1	5	9	3	37
Feeding np51 or other components to reduce calf exposure	0	0	0	1	0	1
Similar discussion on control of Salmonella in beef and poultry	0	0	1	0	0	1
Virulence mechanisms of *E. coli* 0157	1	0	0	0	0	1

create an effective message about STEC pre-harvest control. Over 70% indicated that more than half of the programme content was new to them. Almost all responded that the programme was relevant to their work and gave the programme an overall high rating. When asked to provide items they wanted to share with others, the major themes were as follows: (i) new information on super-shedders, (ii) grass-fed versus grain fed cattle and (iii) how to build good communication strategies. Videos from this conference were posted within a few weeks of the conference date, and there were 348 Internet visitors to them within 1 month of posting on the project website (http://extension.wsu.edu/vetextension/ec/Pages/default.aspx).

Conference 3 (November, 2013)

The third conference was held as a 2.5-h webinar and with an on-site audience at Mississippi State University. In addition to the webinar and on-site audience, eight live Twitter feeds were provided to 203 followers prior, during, and at the end of the webinar. There were 10 additional followers after the webinar. Twenty-six people attended the on-site event, and 155 people were registered for the webinar with approximately 80 people logged in at any one time. Thirty-five individuals completed the programme evaluation. Most of the participants registered (37%) were students, 20% were extension educators, 17% were in government

food safety/public health practitioners, 9% were dieticians and 9% were academics. Most respondents to the evaluation (>97%) ranked the programme good to excellent, relevant to their work, met the stated objectives, and the length of the programme was appropriate.

For 25% of participants completing the evaluation, almost all the information was new to them. As in Conference 2, we focused on myths identified through the literature review and environmental scan. When asked 'What was one new thing you learned that you want to share with others in your work?', 28% would specifically share that grass-fed beef was not safer than grain-fed beef and 21% would specifically share information on use and effectiveness of cattle vaccination to reduce *Ec*O157 shedding. Fourteen per cent reported that they would take back information on message mapping or delivering messages. To evaluate the programme's primary objectives, participants were asked their level of agreement with three statements. Sixty-five and 35% of respondents strongly agreed or agreed (respectively) with the statement 'I better understand the complexity of pre-harvest STEC control'. Fifty-one and 49% of respondents strongly agreed or agreed (respectively) with the statements 'I better understand how cattle feeds and production systems affect STEC shedding' and 'I feel confident I can create an effective message about beef food safety'. In the month following the third conference, 181 page views of the video recordings from this conference occurred on the project website.

Web-based programme for science-writers

Three fact sheets and narrated slide set programmes for science-writers and the public were created: 'Weighing the Evidence: Part I: A Guide to Thinking About *E. coli* O157:H7; 'Part II: It's How We Feed Cattle That Leads to *E. coli* O157:H7 Shedding, Right?' and 'Part III: What Measures Do We Have to Reduce *E. coli* O157:H7 Shedding From Cattle?'. These were posted in 2013. The narrated programmes received 11, 4 and 7 views, respectively, within 3 months of posting.

Discussion

This outreach project provided the current state of scientific evidence for issues surrounding pre-harvest control of *Ec*O157. This information was delivered to a variety of audiences in a variety of methods with an emphasis on virtual conferences and web-based materials and provided information that could improve communication of this evidence. The programmes reached more than 800 people, most of whom indicated that they would share some of the information with others. Veterinarians and others in public health, regulatory medicine, private practice, extension educators in livestock science, nutrition and dietetics, and producers can all influence others and increase the impact of an Extension education programme through the multiplier effect (Flowers and Harris, 1981). Most of the programme audience was reached through virtual conferences.

Despite some of the technological limitations for delivering and receiving the information, virtual conferences are becoming more popular (Welch et al., 2010) and can efficiently engage a larger audience than traditional conferences. Although these conferences will not totally replace face-to-face conferences, they do provide an economically efficient way to engage a spatially diverse audience. With the ability to provide for enduring materials, such as videos posted after a synchronous programme, the reach of information can be even greater as it allows asynchronous participation of an audience unable to attend a conference because of time differences or competing events.

A web monitoring tool to track information being openly shared about STEC and cattle was used to 'listen in' on the Internet conversation about STECs. This is an innovative and powerful tool for extension educators and others to understand and monitor the need for information sought out by their clientele. It also provided insights on sources for the information circulating on the web and media. This method of needs assessment, using a daily Internet environmental scan over an extended period of time, helped shape the content and messages for the outreach programme audiences. The creation or emphasis of particular content in the outreach materials was focused on myths that appeared on the Internet. The technique of environmental scanning is not new to assessment of learning needs and has been adapted to public health needs assessment (Rowel et al., 2005). However, to our knowledge, use of this specific method of a daily Internet search is unique to Extension education content development. One reason to focus on common misconceptions is that the more media attention that is put onto a food safety topic or the more prevalent a problem is, the more likely consumers are to rank it as a major concern for them (Webster et al., 2010).

The review of the pre-harvest EcO157 control literature provided evidence for much of the programmes' content. Because of the focus on perpetuated misinformation, very specific learning objectives for the first, large webinar could be made and evaluated. The major changes in audience knowledge included the real risk of *Ec*O157 in meat from grain-fed versus grass-fed cattle, the efficacy of pre-harvest vaccination, and cattle production systems did not influence *Ec*O157 shedding rates.

The follow-up face-to-face meeting with government veterinarians, industry representatives and others in the Washington, DC, area was developed as a result of the evaluation from the first webinar. Specifically, more in-depth

information on the role of cattle in the epidemiology of *Ec*O157, how cattle feeding influences shedding and how science can inform policy-making was provided. In addition, participants were able to use the information they had just heard, after learning some methods in risk communication, specifically message mapping, to identify and create messages they would like to share with others (Covello, 2002). Although we did not evaluate this technique to extend our messages or content, we could speculate that if the participants 'owned' the message because they created it, they might actually use it. From the live conference, attendees changed their perspective on the role that cattle feeding and production type had on shedding rates in cattle. Although the numbers of attendees were low, after posting videos of all the presentations, there was a large number of website 'hits', indicating new interest in the information provided at the conference.

This project did not directly address consumers. Instead, outreach focused on reaching policy makers, regulators, public health and extension educators that could, eventually, influence consumers. A wide range of audiences were selected because there are differences in different consumer segments with regard to their level of trust and use of information sources about food safety (Kornelis et al., 2007). Although similar messages were provided in each programme, the focus, delivery and depth of content varied by audience. In addition to the range of audiences, the first webinar reached a number of people at many different locations. Anecdotally, participants were not necessarily watching the webinar alone. Some individuals reported having multiple people in attendance at one location. The second conference was focused on policy-makers. Although more from the first webinar indicated that they would be interested in a live conference, fewer actually participated than anticipated and the individuals attending were different. When bringing a conference to the audience, a face-to-face meeting still suffers from the need to travel, schedule conflicts and devoted time.

The third conference was focused on individuals who would influence consumers directly through nutrition advice. Both on-site webinar and Twitter audiences were provided information. Twitter messages did not move beyond 10 new followers within 24 h of posting. In an evaluation of Twitter for training programmes, although deemed valuable for online formative evaluation and providing an opportunity to supplement traditional educational methods, a number of issues have been raised about their educational use including the lack of participants' commitment for peer to peer collaboration (Chen and Chen, 2012). What this could mean for the *Ec*O157 messages we sent is that there is not a commitment by the audience to forward messages to others. The incorporation of these newer technologies into educational programmes most likely requires additional forethought and design (Junco et al., 2012).

The science writer audience proved difficult to reach directly. We learned through their organizations that for their continuing education, they are not as interested in content information as in delivery methodology and work-related issues. With the advent of digital media, there are fewer science journalists in traditional media and more science blogging (Brumfiel, 2009). The online science journalists take on a variety of professional roles (conduit of information, agenda-setter, watch-dog, investigative reporter, advocate, civic educator, etc.) because they no longer are the only conveyers of science information to the public (Fahy and Nisbet, 2011), and few journalists see their job as promoting the benefits of science (Allan, 2011). It is for these reasons that our science, evidence-based programmes likely did not meet the needs of this audience.

In conclusion, this outreach project integrated current research, with many of the researchers themselves as speakers and educators, Internet environmental scanning for needs assessment and a number of methods to disseminate the information to a range of audiences. This project specifically targeted common myths about the risk of cattle shedding *Ec*O157 and provided current evidence on pre-harvest measures to reduce *Ec*O157 shedding in cattle and sources of the pathogen; science that could guide policy-making; and message development. From programme evaluations, several misconceptions about cattle production practices were dispelled, and pre-harvest control measures were better understood.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Published Literature on Dietary Components that Affect the Carriage of Shiga-Toxin Producing *Escherichia coli* O157 (STEC O157) in cattle.