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Knowledge and Attitudes of Produce and Seafood Processors and Food Safety Educators Regarding Nonthermal Processes

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Abstract: A needs assessment survey was designed and administered to measure knowledge of and attitudes toward food safety impacts of nonthermal processing technologies of shellfish and produce industry personnel and extension educators. An online survey was sent via e-mail notification with the survey link through professional listserves. The survey evaluated background information, knowledge, attitude, and training needs. A variety of response formats was used. Knowledge/attitude responses were analyzed using descriptive statistics, 1-way ANOVA and *t*-tests using SPSS software and reported at $P < 0.05$. Industry ($N = 106$) and educator ($N = 52$) respondents had below the proficient knowledge score (80%), 50% and 67%, respectively. Question reliability was >0.9. There were no differences in attitudes and knowledge between the 2 industry groups. The total attitude score, based on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), of the produce and shellfish industry and educator respondents toward nonthermal processing technologies was 3.6 ± 0.4, 3.4 ± 0.5, and 3.6 ± 0.4, respectively. Respondent's slightly indifferent attitude may reflect low knowledge regarding the impact of nonthermal processing technologies on food safety and quality. Both groups indicated a desire for information and/or training. For both industry and educators, common preferred formats for outreach resources were printed materials, Internet/web-based materials, and PowerPoint. Educators identified barriers as equipment cost, lack of information, and lack of product validation. While the majority of the respondents were aware of nonthermal processing, they were not knowledgeable, indicating a need for education and outreach in nonthermal processing methods to both shellfish/produce industry and food safety educators.

Introduction

Alternative, nonthermal food processing/preservation methods have been investigated for many years, and are methods of current interest since they exert minimal impact on nutritional and sensory attributes of food while at the same time extending shelf life and enhancing safety by killing microorganisms (Morris and others 2007). There have been numerous reviews focused on nonthermal technologies that are being investigated for a wide variety of food products and include: high-pressure processing (HPP), chemical disinfection, ultraviolet light (UV), pulsed light, gamma irradiation, cold plasma, ozone, and e-beam (IFT Scientific Panel 2000; Butz and Tauscher 2002; Morris and others 2007; Pereira and Vicente 2010). The emergence of novel nonthermal technologies allows for the production of high-quality products with improvements to quality, safety, and energy efficiency (Morris and others 2007; Pereira and Vicente 2010).

Of particular interest recently are the impact of nonthermal technologies on fresh produce and shellfish. Viruses and bacteria have been implicated in causing foodborne illness in raw or undercooked shellfish and fresh produce. While there are preventative programs (Good Agricultural Practices [GAPs] and Hazard Analysis Critical Control Points [HACCP]) that are directed toward minimizing the foodborne risks for both these commodities, contamination with foodborne pathogens often still occur, and a decontamination step prior to consumption is still desired. Traditional thermal processing for these 2 commodities is not feasible when these products are consumed as raw products, due to the sensory changes that occur due to thermal processing. Alternative nonthermal processing methods are currently being investigated as a means to enhance safety of these foods while retaining the fresh sensory characteristics of the product that consumers demand.

While these nonthermal processing methods have potential food safety impacts, industry/educator awareness and knowledge of these novel techniques has not been well investigated. Ultimately, consumer attitudes toward these new technologies will influence their success in the marketplace (Cardello and others 2007).

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However, prior to targeting consumers for outreach education and promotion of alternative technology, efforts must be directed toward industry personnel and food safety educators. Therefore, prior to promoting specific nonthermal processing methods, shellfish and produce industries, and extension educators, need to be assessed for their current knowledge of, and attitudes toward nonthermal processing technologies. In response to this, a needs assessment survey was developed for the produce and seafood industries, and extension educators, to establish the knowledge and attitude toward nonthermal/alternative processing methods currently being evaluated for produce and seafood products. The results of this survey will identify knowledge gaps and attitudes toward the most promising nonthermal processing methods being evaluated by food safety researchers. The development of outreach education materials regarding nonthermal processing technologies for produce and seafood commodities will be directed by the results of the needs assessment. The outreach resources developed will be evaluated by the project research team, produce and shellfish industry members, government, and educators.

With the development of outreach resources focused on nonthermal processing, we hope to improve the base knowledge of workers in the produce and seafood industries, as well as provide outreach resources for extension educators and the public. It is anticipated that as these nonthermal processing methods are made commercially available to the respective industries, the adoption of these technologies by the produce and seafood industries may be facilitated by their understanding and familiarity of these processing methods, and long-term enhancement of the safety of their products for consumers. Specific objectives of this project included implementation of a needs assessment to determine the knowledge/attitudes, preferred outreach formats regarding nonthermal processing technologies for produce/shellfish industry and education audiences, and the development of outreach resources and strategies to communicate the results to stakeholders (produce and shellfish industry, educators, government, and consumers).

Materials and Methods

Sampling and data collection

Online surveys were developed and administered (Survey Monkey®) to 2 target audiences: 1) produce and shellfish processing industries and 2) food safety extension educators. The survey for shellfish (dealers, wholesalers, and harvesters of wild and aquacultured shellfish) and fruit/vegetable producers was launched in July of 2012 and data were collected through September 2012. A similar survey for educators was launched in November 2012 and data were collected through December 2012. Survey implementation followed the protocol previously outlined by Pivarnik and others (2006, 2009) and Hicks and others (2008, 2009). Potential participants received a notification of the survey link by e-mail through industry or educator professional listserves or via newsletter. The shellfish industry was solicited using listserves from the East Coast Shellfish Growers Assn. ($N =$ approximately 650), the West Coast Shellfish Growers Assn. ($N =$ approximately 150), and Interstate Shellfish Sanitation Conference ($N = 55$). Produce industry personnel were solicited using a United Fresh Produce Assn. listserve ($N = 120$) and the Produce Safety Alliance newsletter ($N =$ approximately 400). Educators were solicited through the USDA Food Safety Educator listserve ($N = 284$) administered through the Natl. Inst. of Food and Agriculture (NIFA), and the Food and Nutrition Professionals Who Educate the Public (FN-SPEC) listserve ($N =$ approximately 650) administered through Purdue Univ. One e-mail reminder was sent to the target audiences. Survey distribution return rate could not be determined because all listserves/mailing lists included multiple audiences. Lists contained regulators, growers, researchers, wholesalers, foodservice personnel, educators in a variety of disciplines, and other interested parties.

Questionnaire

Both industry and educator surveys included 4 sections: background information; knowledge about the principles, applications, and food safety impacts of nonthermal technologies; attitudes and beliefs about new technologies; and training needs regarding nonthermal processing. Respondents were asked to check all that applied for specific questions that had, potentially, more than 1 answer. The background section for respondents contained questions that were specific to the audience (for example, company size and products produced compared with academic background and students taught) and questions common to both (for example, region, awareness of nonthermal processes, and food safety training). The same 28 knowledge questions were used for both industry and educator surveys. A variety of response formats were used. These questions were graded as right or wrong. The response for knowledge questions was agree, disagree, or don't know. For purposes of statistical assessment, "don't know" reflected a lack of knowledge and was considered an incorrect answer. Subject mastery or proficiency, at 80% correct, has been used previously to evaluate the knowledge base of diverse audiences (Pivarnik and others 2006, 2009; Hicks and others 2009, 2013). Knowledge items were grouped into 2 categories: general information regarding nonthermal processes and specific knowledge regarding specific nonthermal processing techniques. Attitude statements related to nonthermal/alternative processing were rated on a 5-point Likert scale, with 1 = strongly disagree to 5 = strongly agree. Industry and educator respondents rated 13 and 15 attitude statements, respectively. There were 12 attitude statements that were common to both audiences, and 3 additional statements were tailored to educator survey audiences, and 1 additional statement was tailored to the industry audience. Both industry and educator survey respondents were queried regarding format preferences for training and information updates on nonthermal/alternative processing technologies.

The protocol and questionnaire were approved by the Univ. of Rhode Island Institutional Subjects Review Board. Prior to implementation, the survey items were reviewed for content validity and clarity. Twenty-two experts reviewed the industry survey and 13 reviewed the educator survey. Experts were solicited from Land Grant and Sea Grant Cooperative Extension programs, academic institutions, and the project advisory panel. The questionnaires were revised prior to distribution based on these recommendations.

Animated videos

Two animated videos were created in partnership with New Mexico State Univ. (NMSU) and posted on You Tube and NMSU websites. Video 1, entitled "Keeping Produce and Shellfish Safe to Eat without Heat," was an overall review of nonthermal processing technologies and food safety (https://youtu.be/0n0Rom8nBFw). Video 2, entitled "Exploring Specific Non-thermal Processes to Enhance the Safety" addressed more detail regarding specific nonthermal processing technologies (https://youtu.be/KJd_LJR2ypk). Requests to review the videos were sent via listserves, as previously described in

Sampling and Data Collection. In addition, FDA/CFSAN reviewers were requested, and were solicited by e-mail lists administered by the FDA. The videos posted to an NMSU website (http://aces.nmsu.edu/nonthermal/) had a Survey Monkey link for reviewers to complete an evaluation and was not made public until the evaluation period was completed. A total of 85 and 66 reviewers evaluated Video 1 and Video 2, respectively, for importance, usefulness, and relevance to target audience (educators, consumers, and industry) as well as any additional comments. Reviewers rated the video for importance and usefulness of information using a 5-point Likert scale (1 = very poor; 5 = excellent). Reviewers consisted of produce/shellfish industry personnel, food safety/nutrition/academic educators, and FDA/CFSAN government officials.

Data analysis

Data analysis was carried out using the SPSS statistical program (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY). Descriptive analysis (for example, frequencies, percents, means, ranges, and standard deviations), 1-way ANOVA, followed by the Scheffe's post hoc procedure, and *t*-tests were run to determine statistical significance between means. Chi-square statistics were run when the relationships between variables were examined for observed compared with expected frequencies. Reliability was examined using Cronbach's alpha measure of internal consistency. Significant findings were reported at $P < 0.05$, as noted.

Results and Discussion

Demographic characteristics

If respondents did not have their primary business as produce or shellfish, or they were not food safety educators, they were disqualified from completing the survey ($N = 12$ for both industry and educator). Database results included both partial, when appropriate, and completed surveys. Table 1 and 2 show the key background characteristics of both the industry ($N = 106$: Produce $N = 27$, Shellfish $N = 79$) and educator ($N = 52$) survey respondents, respectively.

Produce industry

The majority of produce respondents identified themselves as a manager (HACCP/food safety, packing house, quality assurance, quality control, or receiving) (78%) and 8% as owners (data not shown). Of the respondents, 77% indicated the business they work for employed over 150 people and 71% of the produce respondents indicated farming over 1000 acres—with 21% farming on more than 10000 acres. Many of the produce industry respondents (74%) had been in business more than 20 y. While producers were located throughout the 4 census regions of the United States, 82% of produce respondents were located in the West, followed by 33% from the South. Only 22% identified themselves as growers with 63% indicating they operated packing houses, 37% were shippers, 33% operated warehouses, and 22% to 26% were processors, exporters, or importers. The majority of the produce grown/handled would be considered higher risk by the FDA (Vandeputte and others 2015), such as leafy greens, fruit vegetables, stone fruit, berries, and melons (data not shown).

None of the respondents indicated involvement with community-supported agriculture (CSA)), farmers markets, or pick-your-own. The only direct consumer marketing conducted was on farm stands (4%) (data not shown). The majority of fruit (78%) and vegetable (70%) products handled received no or minimal processing (that is, cutting) (data not shown). Eighty-nine percent of the respondents indicated that they had received food safety training with GAP implementation, GAP certification, and established food safety plans at 91%, 78%, and 100%, respectively. In a 2004/2005 multistate study by Jackson and others (2007) on the impact of GAPs, the awareness was high but there was some resistance to implementation independent of farm size. Awareness of GAP principles resulted in the increased likelihood of providing facilities necessary to enhance worker hygiene. In the 10 y since the survey was conducted, it would appear that the importance of food safety knowledge and practices has increased significantly. Survey respondents reflected farms of large size indicated by acreage and number of employees. Thirty-six percent indicated that they had over 501 employees. Of producers who classified themselves as growers ($N = 18$), 93% reported farm acreage over 1000 and 27% had over 10000 acres. The respondent pool reflects large farms that supply the majority of produce to U.S. consumers.

Seafood industry

The majority of shellfish industry respondents identified themselves as the CEO/president and owner (65%; data not shown). Unlike the sizeable west regional representation by the fruit/vegetables producers, the majority of the shellfish industry respondents were from the northeast (43%) and southern (37%) regions (Table 1). The majority of respondents represented small operations with 58% reporting 5 or less employees. The type of shellfish businesses reported included aquaculturist (59%), harvester (36%), wholesaler/distributer (35%), and processor (33%). Shellfish products produced or harvested were oysters (74%), clams (38%), and mussels (5%). Fifty-three respondents indicated that they processed/wholesaled products with fresh and/or frozen shellstock (61%) and fresh and/or frozen shucked raw oysters, clams, and/or mussels (20%) as the major products. Other processes, 1% to 6% of respondents, included canning, HPP, cooked/ready to eat, pasteurizing, and irradiating (data not shown).

Unlike the produce industry, the seafood industry has had food safety regulatory requirements for finfish and shellfish since 1997 (21CFR123). The regulation required either formal HACCP training for processors/dealers or proof of training through job experience. Harvesters are not required to have training unless there are state-specific regulations. Therefore, it was not surprising that even though the shellfish industry respondents in this survey represented small companies, that 62% of respondents indicated that they took seafood training courses to meet the requirements of the FDA Seafood HACCP regulation, 14% indicated that they received on-the-job training, and 24% indicated that training was not required.

Food safety educators

Of the 64 food safety educator respondents who initially answered the survey, 52 (81%) described themselves as food safety educators, with a fairly equal distribution over the 4 U.S. census regions (Table 2). Academic background or professional training included food safety (89%), food science (69%), microbiology (54%), agriculture (33%), food processing/engineering (31%), and seafood science (15%). The majority (46/52, 89%) of respondents received specific food safety-related training. The type of trainings attended were HACCP or HACCP-related (85%), sanitation (61%), manager certification (52%), good manufacturing practices (41%), and GAPs (39%). The majority (80%) of educators

Table 1–Background information of produce and shellfish industry respondents ($N = 106$: Produce $N = 27$, Shellfish $N = 79$).

	Produce ($N = 27$)		Shellfish ($N = 79$)	
	Frequency	%	Frequency	%
Region[a] (checked all that applied) (Produce $N = 27$; Shellfish $N = 76$)				
Northeast	4	15	37	47
Midwest	4	15	1	1
South	9	33	32	41
West	22	82	13	17
Years company/firm/farm in respective business (Produce $N = 27$; Shellfish $N = 72$)				
Less than 1 y	–	–	3	4
1 to 5 y	1	4	17	22
6 to 10 y	–	–	10	13
11 to 15 y	3	11	7	9
16 to 20 y	3	11	8	10
More than 20 y	20	74	34	39
Total number of employees at company/firm/farm (Produce $N = 27$; Shellfish $N = 76$)				
1 to 5 employees	–	–	46	58
6 to 15 employees	–	–	9	11
16 to 25 employees	–	–	9	11
26 to 50 employees	1	4	2	3
51 to 150 employees	4	15	9	11
151 to 500 employees	11	41	4	5
501 to 1000 employees	5	18	–	–
Greater than 1000 employees	5	18	–	–
Not sure	1	4	–	–
Acres used for production (Produce $N = 24$; Shellfish N/A)				
Not applicable/not a grower	6	25		
<1 to 100	–	–	–	–
101 to 500	1	4	–	–
501 to 1000	–	–	–	–
1001 to 5000	8	33	–	–
5001 to 10000	4	17	–	–
>10000	5	21	–	–
Type of business[b] (checked all that applied) (Produce $N = 24$; Shellfish $N = 73$)				
Packing house	17	63	–	–
Shipper	10	37	–	–
Refrigerator/frozen storage warehouse	9	33	–	–
Importer	7	26	–	–
Exporter	7	26	–	–
Fresh vegetable processor	7	26	–	–
Fresh fruit processor	6	22	–	–
Owner grower/farmer	6	22	–	–
Shellfish aquaculturist	–	–	51	59
Shellfish harvester	–	–	31	36
Wholesaler or distributor	–	–	30	35
Shellfish processor	–	–	28	33
Shucker/packer	–	–	17	20

[a] Some produce respondents indicated more than 1 region.
[b] Type of business is indicated for categories where ≥20% respondents answered.
N/A = Not Applicable.
Note The specific number of respondents (N) is indicated with individual questions to indicate where some respondents did not answer the question.

indicated that they had more than 11 y of experience teaching food safety-related information/subjects and 81% are currently teaching food safety classes/workshops (Table 2). Educators primarily worked in an academic setting (87% self-designated academic/extension/university), with diverse target audiences that included students (71%), foodservice personnel (46%), farmers (42%), produce industry personnel (29%), retail industry personnel (24%), meat/poultry industry personnel (20%), and seafood industry personnel (17%). Corresponding workshops offered were HACCP, GAP, GMPs, and sanitation.

Knowledge and awareness of nonthermal processing

Table 3 and 4 show the knowledge mean scores for content categories and item level statements for industry and food safety educator participants. Total knowledge had an alpha reliability of ≥0.9 for all 3 target audiences (Table 3), indicating that the data were reliable for knowledge measures. In addition, content category reliability ranged from 0.79 to 0.94, all reflecting reliable question configuration. Byrd-Bredbenner and others (2007) found that Cronbach alpha coefficients of internal consistency of even slightly lower than 0.70 was found to be reliable. Produce and shellfish industry members and educator respondents had below subject mastery or proficiency with scores of 51%, 48%, and 67%, respectively. Questions reflected both process-specific and general nonthermal processing information. There were no differences in knowledge between the produce and seafood industry groups. While the food safety educators had significantly higher knowledge ($P < 0.05$) for total and categorical nonthermal processing knowledge, they were still below the 80% mastery score.

Questionnaire respondents were given a list of 13 traditional (for example, blanching, pasteurizing, microwaving, and smoking) and 13 alternative food processing methods (for example, high pressure, ozone, ohmic heating, pulsed light, and irradiation) and asked to check all the methods with which they were aware (Table 5). With the exception of concentrating (67%) and ultra-high temperature (UHT) processing (78%), the frequency of awareness for food safety educators was 80% to 100% ($N = 51$; data not shown). Industry awareness ($N = 92$) of traditional food

Table 2–Demographic characteristics of food safety educator respondents ($N = 52$).

	Frequency	%
Region ($N = 51$)		
Northeast	11	22
Midwest	14	27
South	16	31
West	10	20
Length of time worked in current position ($N = 51$)		
Less than 1 y	1	2
1 to 2 y	3	6
3 to 5 y	4	8
6 to 10 y	7	13
11 to 15 y	9	17
More than 15 y	28	54
Years of experience teaching food safety-related information/subjects		
Less than 1 y	–	–
1 to 5 y	4	8
6 to 10 y	6	12
11 to 15 y	13	25
16 to 20 y	8	15
More than 20 y	21	40
Currently teach food safety classes/workshops		
Yes	42	81
No	10	19
Target audiences for food safety classes/workshops[a] (checked all that applied) ($N = 42$)		
Students	29	71
Foodservice personnel	19	46
Farmers	17	42
Produce industry personnel	12	29
Teachers	11	27
Retail, direct to consumer	10	24
Meat/poultry industry personnel	8	20
Health providers	7	17
Seafood industry personnel	7	17
Juice manufacturers	5	12
Food safety classes/workshops taught to industry[a] (checked all that apply) ($N = 41$)		
HACCP—processing industry	17	42
GAP	15	37
GMP	14	34
Sanitation	16	39
Manager Certification/ServSafe	13	32
HACCP—food service	8	20
Prerequisite programs—other than sanitation	5	12
SQF certification	2	5
Teach food safety to industry employees ($N = 47$)		
Yes	22	47
No	*25*	*53*

[a] *Educator* respondents currently teaching food safety were asked to indicate target audiences and food safety classes taught ($N = 42/52$).
The specific number of respondents (N) is indicated with individual questions to indicate where some respondents did not answer the question.

Table 3–Level of knowledge regarding nonthermal processing technologies for produce and shellfish industry and educator respondents: total, specific, and general content categories.

	Mean % correct ± standard deviation (Alpha reliability[a])		
Knowledge area	Shellfish industry $N = 48$ to 60	Produce industry $N = 21$	Educators $N = 48$
Total (28 items)	51 ± 24 (0.90)[a]	48 ± 30 (0.95)[a]	67 ± 25 (0.92)[b]
Specific nonthermal processing information (13 items)	45 ± 26 (0.79)[a]	44 ± 28 (0.84)[a]	61 ± 27 (0.84)[b]
General nonthermal processing information (15 items)	56 ± 27 (0.87)[a]	52 ± 36 (0.94)[a]	74 ± 26 (0.88)[b]

[a] Alpha reliabilities were calculated on complete sets of data as follows: Produce $N = 21$, Shellfish $N = 48$, Educators = 48.
[a,b] Different letters indicate significant ($P < 0.05$) differences between respondent groups and within knowledge content categories.

processing methods was, as expected, much higher overall than alternative, nonthermal methods. Sixty-five percent to 79% of industry respondents were aware of 6 of the 13 choices (for example, blanching, canning, cooking, freezing, pasteurizing, and smoking) and over 50% to 64% were aware of 3 alternative, nonthermal choices (drying, freeze-drying, and salting/brining). Concentrating (27%) and fermenting (33%) had the lowest awareness (data not shown).

More than half of the produce industry (52%), shellfish industry (68%), and educator (71%) respondents claimed to be aware of nonthermal processing techniques (Table 5). Both educators and industry personnel ranked the same alternative methods in the top 4—high pressure, irradiation, ozone, and UV light—as the ones with which they were most familiar. Educators also ranked these same 4 processes as those they felt most knowledgeable about. After these 4, industry awareness of all other non-thermal processes

Table 4–Item level of knowledge regarding nonthermal processing technologies for produce and shellfish industry and educator respondents, categorized into specific and general content areas.

	Mean % correct		
	Shellfish industry $N = 48$ to 60	Produce industry $N = 21$	Educator $N = 48$
Specific nonthermal process information			
Irradiation sources for treating foods are the same as used in nuclear power plants. **[I]**[a]	67	57	86
High-pressure processing is already commercially used for certain ready-to-eat produce and seafood products. **[C]**[a]	72	52	69
Eating UV treated food causes cancer. **[I]**	76	62	94
Sanitation procedures are not important if nonthermal processes are used to treat food. **[I]**	83	86	94
Irradiation cannot be used to treat frozen foods. **[I]**	34	29	57
Bacteria can be killed by ozone treatment. **[C]**	50	62	60
High-pressure processing is performed on prepackaged food products. **[C]**	30	33	60
Puffed wheat and rice cereal products are manufactured using nonthermal high-pressure processing equipment. **[I]**	8	14	34
UV can be used to treat the internal portion of shellfish and produce to help increase safety. **[I]**	27	28	47
High fat containing foods treated with UV or ozone could develop off-flavors. **[C]**	19	19	55
If strawberries or shrimp are irradiated, they would not require labeling that identifies them as being treated by irradiation. **[I]**	40	38	70
Since ozone degrades to oxygen after its use, there would be no dangers or environmental concerns. **[I]**	25	52	38
Sanitizers can be used as an alternative processing method on food products. **[C]**	6	38	24
General nonthermal process information			
In order to make foods safe, heat must always be used. **[I]**	90	95	96
Nonthermal food processing methods being developed can be used to help keep food safe from foodborne disease-causing bacteria. **[C]**	68	67	75
Nonthermal food processing methods being developed can be used to help keep food safe from foodborne disease-causing viruses. **[C]**	47	38	58
Once an alternative processing method is proven effective for safety on 1 food product it can be used on any product in the same way. **[I]**	68	72	92
Nonthermal processed foods require no refrigeration after being processed. **[I]**	58	57	69
Nonthermal processing makes food sterile. **[I]**	52	38	75
In most cases, nonthermal processing retains more nutrients in the food than thermal processing. **[C]**	32	43	54
Foods treated with nonthermal processes are safer to eat than untreated (for example, raw oysters, sprouts). **[C]**	33	33	72
Since some foodborne disease-causing bacteria can grow at refrigeration temperatures, nonthermal processing techniques would not be effective at killing these bacteria. **[I]**	46	52	71
Nonthermal processes are currently not being used in the food industry. **[I]**	67	43	81
The same nonthermal treatment proven (validated) to kill foodborne disease-causing bacteria can be used to kill parasites. **[I]**	24	14	44
Nonthermal and thermal processes used to treat food for safety have to be proven (validated) for their effectiveness against foodborne disease-causing micro-organisms. **[C]**	70	62	81
Nonthermal processing will help eliminate all chemical toxins already present in food. **[I]**	72	57	85
As with thermal processing, nonthermal processing cannot eliminate heavy metal contaminants in food. **[C]**	68	52	75
Nonthermal processing can extend the shelf life of foods. **[C]**	42	57	79

[a] Knowledge statements are identified as correct [C] and incorrect [I]. Mean % correct reflects respondent accurately agreeing or disagreeing, as appropriate with the statement as it is written.

Table 5–Industry and educator respondent awareness of new/alternative food processing technologies and the top 4 ranked technologies.

	Percent (%)	
Awareness and technologies[a]	Industry[b] $N = 92$	Educators $N=51$
Awareness	64	71
Irradiation	70	86
High pressure	61	75
Ultraviolet light (UV)	54	73
Ozone	50	69

[a] Respondents checked all that apply for techniques they are most aware of.
[b] Industry includes Produce ($N = 23$) and Shellfish ($N = 69$).

dropped to 3% (ohmic heating, electromagnetic) to 20% (X-ray). Following the top 4, educator awareness ranged from 21% (electromagnetic) to 45% (electrolyzed water) (data not shown). Awareness of high-pressure technology ranked highest with health professionals (Delgado-Gutierrez and Bruhn 2008); but their choices did not include irradiation. These researchers hypothesized that there was a greater comfort level with high-pressure technology since this appeared to be the most developed technology, with a high degree of safety and effectiveness and more products currently in the marketplace. Of the educators surveyed, 47% ($N = 22/47$) taught food safety to industry employees and only 50% ($N = 11/22$) of those educators incorporated information about nonthermal processing into their classes and felt knowledgeable about the technologies. However, as indicated by the knowledge-based portion of the questionnaire, neither industry nor educators were proficient in knowledge relating to food safety impacts of nonthermal processing technologies—regardless of food safety training received. This could be due to the fact that the primary trainings attended by educators and industry (for example, HACCP, sanitation, and GMP) do not target processing and food safety of alternative processing methods.

Table 6 shows attitude scores of industry and educators, respectively. Total attitude of the produce and shellfish industry and educator respondents toward nonthermal processing technologies indicated that they were rather indifferent, with average scores, on a Likert scale of 1 to 5, were 3.6 ± 0.4, 3.4 ± 0.5, and 3.6 ± 0.4,

Table 6–Produce and shellfish industry and educator respondents' attitudes toward food safety procedures related to nonthermal/alternative processing technologies.

	Average score[a] ± Standard deviation		
	Shellfish industry $N = 47$	Produce Industry $N = 20$	Educator $N = 47$
Food safety is important to me.	4.8 ± 0.4	4.7 ± 0.9	N/A
New food processing technologies are important to keep food fresh longer.	3.9 ± 0.9	3.4 ± 1.1	3.9 ± 0.7
New food processing technologies are important to make food safe.	4.1 ± 1.0	3.5 ± 1.1	4.2 ± 0.7
I am not fearful of new food processing technologies.	4.3 ± 0.9	4.0 ± 1.0	4.1 ± 0.7
Food preservatives are important to the safety of food.	3.1 ± 1.0	2.9 ± 1.2	3.9 ± 0.6
Consumers are most interested in foods that are convenient and easy to prepare.	4.3 ± 0.6	3.6 ± 1.0	4.2 ± 0.6
Consumers are most interested in foods that look and taste fresh.	4.5 ± 0.7	4.3 ± 0.9	4.3 ± 0.6
New food processing technologies are less likely to destroy nutrients in food.	3.2 ± 0.8	2.9 ± 0.6	3.2 ± 0.7
New food processing technologies are less likely to result in food safety problems.	3.0 ± 0.7	3.1 ± 0.8	2.8 ± 0.7
New food processing technologies are less likely to result in environmental problems.	3.0 ± 0.7	2.9 ± 0.6	2.9 ± 0.7
New food processing technologies are less likely to result in higher food prices.	2.7 ± 0.9	2.5 ± 0.8	2.5 ± 0.7
If food is shown to be safer using new processing technologies, consumers will be willing to pay more.	2.7 ± 1.1	2.6 ± 1.0	3.8 ± 0.8
If food is shown to be better quality using new processing technologies, consumers will be willing to pay more.	3.2 ± 1.1	3.2 ± 1.1	3.2 ± 0.8
Shellfish/produce industries have a responsibility to learn about new/alternative technologies to make their products safe	N/A	N/A	4.1 ± 0.7
I believe that it is important for me to increase my knowledge about nonthermal processes	N/A	N/A	4.1 ± 0.7
As an alternative method for food safety control, the subject of nonthermal processing technologies is important for food safety educators to teach.	N/A	N/A	4.0 ± 0.8
Total attitude	3.4 ± 0.5	3.6 ± 0.4	3.6 ± 0.4

[a] Average score was calculated from a 5-point Likert scale: 1=Strongly Disagree, 2=Disagree, 3=Neither, 4=Agree, 5=Strongly Agree.
N/A indicates that the statement was not included in the respondent survey.

Table 7–Top delivery/format preferences for industry and educator respondents to receive training and information updates regarding nonthermal processing technologies.

	PowerPoint presentations	Printed materials	Web-based /Internet	Webinars	CD/DVD
Training					
Industry ($N = 42$)[a]	2	3	1	3	–
Educators ($N = 11$)[b]	1	2	4	3	–
Information updates					
Industry ($N = 52$)[a]	3	2	1	–	4
Educators ($N = 16$)[b]	1	3	2	–	4

[a] Industry respondents interested in receiving training ($N = 42/69$) and information ($N = 53/69$) were asked to indicate delivery format preferences.
[b] Educator respondents who taught food safety to industry employees ($N = 22/47$) were asked to indicate their delivery format preferences for receiving training ($N = 11/22$) and information ($N=16/22$).

respectively. Overall, industry personnel and educators surveyed did not have a strong positive attitude toward issues relating to nonthermal or alternative processes for food safety. Both groups surveyed were not overly fearful of new technologies and agreed that consumers were interested in foods that looked and tasted fresh. However, attitude scores fell for industry and educator participants with their perceptions of impacts on nutritional quality, food safety, environment, and consumer willingness to pay for better quality and safety. Only a small number of produce and shellfish industry respondents indicated that they currently use alternative processing methods, 9% and 12%, respectively [for example, high pressure, UV light, ozone, irradiation, and electrolyzed water] (data not shown). Additionally, educators were queried about the barriers to conducting training regarding nonthermal technologies and over 50% indicated that the cost of equipment, lack of information for educators, and lack of validation for use on food products as reasons that prevent incorporation into training. All of the barriers identified could contribute to the potential lack of interest. Ambivalent attitudes and uncertain consumer acceptance coupled to low knowledge base could be a barrier to outreach education (Hicks and others 2013), and therefore, use of new, alternative treatments by industry for produce and shellfish would be hindered.

A lack of knowledge or misinformation about food processing technologies, along with minimal product exposure, can hinder technological progress (Vestal and Briers 2000; Delgado-Gutierrez and Bruhn 2008). The food industry's perception of consumer acceptance of nonthermal food processing technologies, such as food irradiation, has slowed the adoption of widespread commercial application, despite research confirming the safety and effectiveness of this technology in making foods safer for human consumption (Johnson and others 2004). Communication is as important to the acceptance of new technologies as the scientific research. When consumers are presented with clear information about the safety and benefits of food products processed using alternative technologies, their acceptance of and attitudes toward the product/technology increases and acceptance by the end user will ultimately expand the use by the food industry (Bruhn 1995, 2007; Cardello 2003; Delgado-Gutierrez and Bruhn 2008). For example, consumer willingness to buy irradiated products has increased 40%, between 1993 and 2003; however, a large number of consumers continued to answer "don't know" to knowledge

Table 8–Respondent evaluation of the 2 videos illustrating nonthermal processing technologies to enhance the safety of produce and shellfish.

	Percent %					
	Video 1			Video 2		
	"Keeping produce and shellfish safe to eat without heat"			"Exploring specific non-thermal processes to enhance the safety of produce and shellfish"		
Respondent Representation	(N = 85)			(N = 66)		
Industry[a]	17%			15%		
Educator[a]	28%			29%		
Government	52%			53%		
Other[b]	3%			3%		
Video Evaluation – rated as "good and excellent"[c]	(N = 84)			(N = 64)		
Usefulness	75%			83%		
Importance	86%			81%		
Recommend to Target Audience	(N = 83-84)			(N = 64-65)		
	Yes	No	Not Sure	Yes	No	Not Sure
Consumers	87%	5%	8%	80%	9%	11%
Educators	80%	7%	13%	82%	4%	14%
Food Processor	70%	8%	22%	73%	8%	19%

[a]Categories created from combined variables: *Industry* represents produce and shellfish industries. *Educator* includes food safety, nutrition, and academic educators.
[b]*Other* included the retail industry and a biologist.
[c]Based on a 5-point Likert scale: 1=very poor, 5=excellent.

questions, indicating that they are not more informed about the irradiation process (Johnson and others 2004). This is no surprise, as knowledge alone does not increase acceptance of technology; awareness and product exposure, which have increased over the last few decades, have played a larger role in consumer acceptance of irradiated food (Zienkewicz and Penner 2004; Bhumiratana and others 2007; Bruhn 2007).

In addition to shellfish and produce industry personnel and food safety educators, there are other audiences that must be included in the outreach efforts for the dissemination of scientific research-based information to prevent the detrimental effects of misinformation. The news media, often cited as a primary source of information by consumers, have a powerful and immediate influence on public perceptions (Vestal and Briers 2000; Hicks and others 2008, 2009). To provide consumers with accurate information about new food processing technologies, educators, industry professionals, and researchers need to include journalists and news media sources in the discussion to enhance their efforts (Vestal and Briers 2000).

Training and education should emphasize the areas of deficiencies indicated in the survey and will be made available in formats most conducive to the target audiences. Table 7 shows the top 4 delivery preferences for training and information updates. Outreach education strategies should incorporate a combination of the preferred common formats, as indicated by survey respondents. The formats common to both industry and educator groups for receiving training *and* information updates were printed materials, web-based/Internet, and PowerPoint. While web-based education is always a choice, printed materials still remain a top preference. Similar results were reported by Hicks and others (2009, 2013). In these studies, web-based training and Internet postings were ranked high, but newspapers, brochures, government publications, and/or fact sheets were still highly desirable formats for consumers and/or medical professionals. Therefore, the common formats selected by participants were chosen to develop an outreach strategy that could incorporate the preferred resource configurations.

The development of outreach resources, based upon results of the needs assessment, has thus far include a "Frequently Asked Questions" (FAQ) document, and the production of 2 animated videos. The FAQ, developed by Pivarnik and Worobo (2014), aimed to clarify misconceptions and areas of low knowledge, as illustrated by the needs assessment. This FAQ was reviewed by researchers actively working on the application of these technologies to food processing, and who are part of this integrated research and outreach project. This FAQ highlighted potential nonthermal processing methods that are being studied for produce and shellfish and included how they work, barriers to their use, and current industry use. The FAQs were distributed to industry and educators using the listserves previously cited and posted on the internet at the Univ. of Rhode Island website (http//web.uri.edu/foodsafety).

In an effort to more creatively address Internet learning experience, not just downloadable files, videos were developed using animation. Information from the FAQs was used to develop 2 short videos, in partnership with NMSU Video 1, entitled "Keeping Produce and Shellfish Safe to Eat without Heat," was an overall review of nonthermal processing technologies and food safety. Video 2, entitled "Exploring Specific Non-thermal Processes to Enhance the Safety" addressed more detail regarding specific nonthermal processing technologies. Both videos have been reviewed by educators, government (FDA), and industry personnel (Table 8). Of those who reviewed Video 1 (N = 83) and Video 2 (N = 65), more than 70% of respondents rated the importance and usefulness of the information in the videos as "good and excellent." Of those who reviewed Video 1 and Video 2, 70% and 75%, respectively, indicated that they would recommend the video for viewing by a food processor; 79% and 81%, respectively, for viewing by an educator; and 86% and 80%, respectively, would recommend the video for viewing by a consumer (Table 8). Results of the evaluation indicate that this novel animated video, as opposed to more technical videos, can be used to reach multiple audiences with science-based information instead of redesigning target audience outreach materials. As of this time, there have been 355 and 153 views on YouTube for Videos 1 and 2, respectively. Finally, the next step is to develop a compilation slide presentation that integrates elements from both the FAQs and video animations and targets stakeholder audiences in this study as well as consumers.

Conclusion

Viruses and bacteria have been implicated in causing foodborne illness in fresh produce and raw/undercooked shellfish. The best production practices do not guarantee pathogen-free products. Alternative, nonthermal processing methods to enhance the safety of foods can maintain fresh sensory characteristics of the food product as compared to the more traditional food preservation processes. Application of alternative processing technologies is not "one size fits all" and ongoing research is expanding the opportunities for food product development. While these methods have potential food safety impacts, this study shows that industry/educator knowledge of these novel techniques is deficient and attitudes toward nonthermal technologies are not positive. The "neutral attitude" combined with lack of knowledge could make outreach regarding nonthermal processing challenging. Therefore, promotion of specific nonthermal processing methods to shellfish and produce industries, extension educators, and the public should include a comprehensive outreach program using multiple formats.

Targeted outreach strategies are ongoing, and will continue to integrate common formatting strategies preferred by the target audiences. As evidenced by review, the video resources developed for this project would also be applicable to other audiences, such as consumers or the media, to enhance their knowledge and understanding of the various technologies available or being developed to increase the safety of our food.

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