RESEARCH PAPER

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Evaluation of consumers' perception and willingness to pay for bacteriophage treated fresh produce

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Food-borne illnesses caused by bacteria such as enterohemorrhagic *E. coli* and *Salmonella* spp. take a significant toll on American consumers' health; they also cost the United States an estimated $77.7 billion annually in health care and other losses.[1] One novel modality for improving the safety of foods is application of lytic bacteriophages directly onto foods, in order to reduce or eliminate their contamination with specific foodborne bacterial pathogens. The main objective of this study was to assess consumers' perception about foods treated with bacteriophages and examine their willingness to pay (WTP) an additional amount (10–30 cents/lb) for bacteriophage-treated fresh produce. The study utilized a survey questionnaire administered by telephone to consumers in 4 different states: Alabama, Georgia, North Carolina, and South Carolina. The results show that consumers are in general willing to pay extra for bacteriophage-treated fresh produce if it improves their food safety. However, income, race, and the state where a consumer lives are significant determinants in their WTP.

Introduction

An estimated 48 million cases of food-borne disease occur each year in the United States.[2] It is estimated that there were a total of 1,527 foodborne disease outbreaks during 2009-2010, resulting in 29,444 cases of illness, 1,184 hospitalizations, and 23 deaths.[2-3] Among those who get affected, the most severe cases tend to occur in the very old, the very young, people with immune system malfunction, and healthy people exposed to a very high dose of the pathogen causing the contamination. A proportion of these outbreaks has been associated with fresh produce consumption. Indeed, the availability of fresh produce choices to consumers has been steadily increasing in recent years primarily due to changes in agricultural practices, rising income, and other factors.[4] While these innovations have affected numerous fresh produce categories positively, there is a hurdle in attempts to lengthen the shelf life of fresh produce, be it organic or conventional, and ensure its safety for human consumption. In that context, the outbreaks of fresh produce related food-borne illnesses have become all too common in recent years: notable among these are *E. coli* O157:H7 in spinach, *Listeria monocytogenes* in cantaloupes, and *Salmonella* in tomatoes and peppers.[5-7]

In the past, washing with water has been the only choice available to many consumers in regards to their handling of fresh produce before consumption. However, many food scientists believe that washing with water has a minimal effect on the removal of foodborne pathogens from the surface of produce.[8] Thus, additional, safe and effective approaches are required to ensure the produce safety. One such possible approach is the use of bacteriophages to kill foodborne pathogens in fresh produce. The bacteriophage technology represents a relatively novel method to combat foodborne bacteria that may occasionally contaminate fresh produce; treatment with bacteriophages that target those pathogenic bacteria can make the produce safer to eat.[9]

In recent years, it has become widely recognized that bacteriophages have several potential applications in the food industry.[10-12] They are being considered for use as alternatives to antibiotics in animal health, as bio-preservatives in food, and as tools for detecting pathogenic bacteria throughout the food chain.[4] Bacteriophages are natural enemies of bacteria and are not harmful to plants, animals, humans or the environment.[12] They are the most common organisms on earth, and they are naturally found in the environment, including in all fresh foods and in water.[12] Since 2006, the US. Food and Drug Administration (FDA) has approved the use of several phage preparations (in chronological order: ListShield™, Listex™ P100, EcoShield™, and SalmoFresh™) to control foodborne

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pathogens, such as *Listeria monocytogenes*, *Salmonella* spp and *E. coli* O157:H7, in various foods, including ready-to-eat foods.[13-16] Despite these approvals and natural omnipresence of bacteriophages in foods, the idea of applying phages (i.e., bacterial viruses) to foods may seem unorthodox and perhaps even unappealing to some customers who may not be familiar with the nature of bacteriophages, their safety, and their natural ubiquotness in the environment, including foods. Thus, the goal of this study was to evaluate consumer reaction to bacteriophage technology treated fresh produce. To the best of our knowledge, this is the first published study in which consumers' perceptions and their willingness to pay for fresh produce treated with bacteriophages has been evaluated. As part of the survey, it was necessary to (1) let consumers understand the technology being proposed and how its attributes affect demand for fresh produce, and (2) determine whether consumers were willing to pay an additional amount ($0.10-0.30/lb) for fresh produce treated with bacteriophage technology compared to non-treated fresh produce.

The study of willingness to pay has taken on a variety of forms in the applied economics literature for some time now.[17] The most widely used approach has been contingent valuation, which is a questioning technique that asks individuals what they would be willing to pay, contingent on market availability of the product or service.[17-21] Through the use of discrete choice techniques, stated choice experiments, and experimental auction methods, analysts have also derived estimates of money an individual is willing to pay to obtain a product.[22-24]

Though WTP techniques have been applied to examine different issues, they have not been applied to potential market opportunities for bacteriophage technology treated fresh produce. Usage of bacteriophage technology in the fresh produce industry is still fairly limited; therefore, studies of this nature will help the industry to explore the potential for expanding the market. This study also contributes to the literature by providing pertinent information for the fresh produce industry that can help them develop valuable produce to be sold through the grocery market channel that fetch premium prices. As a result of this, fresh produce sales and possibly farmer income could be increased if consumers are willing to pay for fresh produce treated with bacteriophage technology.

In addition to the aforementioned studies, there has been widespread research in the areas of willingness to pay. Some of these previous studies have included both stated preference and revealed preference approaches. Revealed preference studies on WTP examine consumers' actions in actual marketplace settings.[25-27] These studies are, however, rare compared to the stated preference variety because they tend to be more difficult and costly to perform. Stated preference research is a popular method in evaluating willingness to pay (WTP) because it allows the researcher to survey consumers in easily-controlled settings.[25] Furthermore, some studies have even evaluated the same product in both scenarios to test the credibility of stated preference experiments.[28-29]

Table 1. Demographic data on survey participants

Variable	Number of respondents	Percent of respondents
Gender		
Female	132	0.628
Male	78	0.371
Race		
African-American	64	0.304
Caucasian	135	0.642
Hispanic	1	0.004
Other	10	0.047
Education		
Middle school	2	0.009
High school	94	0.447
College	74	0.352
Graduate	40	0.190
Income		
< $10,000	6	0.028
$10,001–$25,000	76	0.361
$25,001–$50,000	66	0.314
$50,001–$75,000	50	0.238
> $75,000	12	0.057
States		
Alabama	41	0.195
Georgia	63	0.300
North Carolina	75	0.357
South Carolina	31	0.147

Results and Discussion

Descriptive statistics

A total of 384 respondents were randomly selected from a pool of 750, maintaining the same proportional percentage per State. The survey was then fielded to 384 respondents and a total of 210 out of 384 completed responses were received—a 55% response rate. This is a remarkably high response rate for a telephone survey. Moreover, the sample is quite diverse in terms of race, educational attainment, and incomes. Of the 210 participants that responded, approximately 44% indicated that they were High School graduates. Also, 35% of the participants responded that a college degree was the highest level of their educational attainment (**Table 1**). There was a fairly balanced distribution among the respondents in regards to income, where we found that approximately 36% of participants fell within the $10,001-$25,000 income bracket; 31% in $25,001–$50,000; and 24% in $50,001–$75,000; and the remaining falling in either under $10,000 or over $75,000 brackets (**Table 1**).

The racial make-up of the respondents also proved to be noteworthy as 30% were African-American, approximately 64% of respondents were Caucasian, and 6% were of other race (see also **Table 1**). Furthermore, roughly 63% of the participants were females and 37% males (**Table 1**). The make-up of the respondents by state were as follows: 19% from Alabama, 30% from Georgia, 36% from North Carolina, and 15% from South Carolina.

Education and gender were hypothesized to be influential in an individual's willing to pay (WTP) as other studies have found

Table 2. A cross tabulation of gender by WTP

Are you willing to pay extra for fresh produce that have been treated using the proposed technology?	What is your gender?		
	Female	Male	Total
No	62.1%	37.9%	100.0%
Yes	62.5%	37.5%	100.0%
Don't Know	83.4%	16.6%	100.0%
Total	63.3%	36.7%	100.0%

to be the case.[30] In that context, in our study, there was some responses-based evidence that a higher percentage of females are willing to pay an extra amount ($0.10–0.30/lb) to have their fresh produce treated with phages. Of those that are willing to pay an extra amount, about 62.5% are females compared to 37.5% for males (**Table 2**). The cross tabulation of race by WTP (**Table 3**) indicated that a higher percentage of Caucasians (74%) maybe willing to pay more, compared to 25% for African Americans. The cross tabulations do not show a significant difference in the responses of consumers based on their education and WTP. We found that 28% of consumers with high school, 31% with college degrees, and 35% with graduate degrees are willing to pay an extra amount for this technology (**Table 4**). A similar cross tabulation between incomes and WTP is presented in **Table 5**. Generally, it seems that higher income is a determinant of consumers' willingness to pay an extra amount for this technology. About 21% of those earning $10,001 to $25,000 indicated they would be willing to pay an extra amount, compared to 26% and 41% for those in the $25,001 to $50, 000 and $50,001 to $75, 000 brackets, respectively. Importantly, our questionnaire was conducted using the assumption that the consumers will pay 10-30 cents/lb of bacteriophage-treated produce. The real anticipated costs, after the technology has been widely implemented by the produce industry, are expected to be significantly lower at approx. 1–5 cents/lb. Thus, it is possible, if not likely, that the responses might have been even more positive if the more realistic (i.e., lower, at 1–5 cents/lb) cost was presented to the survey participants.

Logistic regression analysis

The binary logit model described in Section 2.2 was estimated using the data gathered from the survey. **Table 6** presents the estimation results of the logit model, **Table 7** shows the odds ratios corresponding to the estimates in **Table 6**, and **Table 8** presents the marginal effects. It would be misleading to interpret the sign effects of the explanatory variables from the logistic regression results in **Table 6**. This is because these estimates are log-odds ratios, which may not make a lot of intuitive sense. As a consequence, it is natural to convert the log-odds to actual odds ratios by exponentiating the log-odds (this is shown in **Table** 7). Better still, we compute the marginal effects, which is the effect of each explanatory variable, X_{ij}, on the probability of success (i.e. willingness to pay), holding all other variables constant. Since most of the explanatory variables are discrete, the marginal effects are the differences in 2 predicted probabilities (as illustrated in equation 3). For example, in the case of gender, the marginal effect of the variable *female* is computed as the difference in predicted probability that *female* = *1* and the probability that *female* = *0* (in the case of the individual being male). For a continuous explanatory variable, such as income, the marginal effect is the change in predicted probability of willingness to pay as a result of a unit change in the explanatory variable (income), holding all other factors constant.[15]

Based on the estimation results, income was found to be the most significant determining factor of a consumer's WTP. In other studies, income has been linked to consumers' willingness to pay for consumable goods and services.[31-32] At the one percent significance level, a consumer's income significantly influences their WTP. Thus, all other things remaining equal, higher income households have a higher WTP for bacteriophage treated fresh produce. The odds ratio estimate (2.368) indicates that a household in a higher income bracket has more than double the odds of purchasing bacteriophage treated fresh produce than another household in a lower income bracket, all other things constant. The marginal effect confirms this: moving from a lower income bracket to the next higher income bracket, the probability of willingness to pay increases by 0.126, a statistically nontrivial effect.

The education variable, *college*, was not statistically significant at any conventional level, probably because income and education are highly correlated in the sample. The correlation coefficient between education and income is 0.71. It is typically the case that a person's education level determines their income or vice versa. The non-significance of the gender variable, *female*, in the logistic regression is rather surprising given the graphical analysis presented in the foregoing sections. It appears from the cross tabulation of gender by WTP that females are more willing

Table 3. A cross tabulation of race by WTP

Are you willing to pay extra for fresh produce that have been treated using the proposed technology?	What race do you consider yourself to be?				
	Caucasian	African American/Black	Hispanic	Other	Total
No	60.2%	32.3%	0.6%	6.8%	100.0%
Yes	74.4%	25.6%			100.0%
Don't Know	80.0%	20.0%			100.0%
Total	63.8%	30.5%	0.5%	5.2%	100.0%

Table 4. A cross tabulation of education by WTP

Are you willing to pay extra for fresh produce that have been treated using the proposed technology?	What is the highest grade of school you have completed?				
	Middle school	High school	College	Graduate	Total
No	0.6%	51.6%	32.9%	14.9%	100.0%
Yes	5.1%	28.2%	30.8%	35.9%	100.0%
Don't Know			80.0%	20.0%	100.0%
Total	1.4%	44.8%	34.8%	19.0%	100.0%

to pay for the technology than males, but this is not reflected in the regression analysis.

Furthermore, the logistic analysis showed that a consumer's race and their State of residence were also significant in determining that individual's willingness to pay an additional amount for fresh produce treated with bacteriophage as preservative. In this particular survey, Caucasians had double the odds of willingness to pay an additional amount relative to other races (**Table** 7) at the 10 percent significance level. The observed higher WTP of Caucasians in this study could be due to a knowledge effect. Those who are relatively well-informed about the safety and the food safety benefits of the technology may be more willing to pay for it.

As mentioned earlier, where a consumer lives (State) was also found to significantly affect their WTP. Consumers in the states of Georgia and North Carolina have lower odds of WTP relative to consumers in Alabama. The odds ratios for residents from Georgia and North Carolina are 0.34 and 0.40, respectively. This is further confirmed by the negative marginal effects for residents of Georgia and North Carolina, relative to residents from Alabama (**Table 8**). It is possible that this difference in willingness to pay for fresh produce treated with bacteriophage technology by state of residence is due to a "knowledge effect" which also indicates the higher income of consumers in those states. The residing State of a respondent may affect their willingness to pay, due to higher awareness and/or knowledge of the proposed technology. In summary, our analysis shows that consumers are in general willing to pay extra for bacteriophage-treated fresh produce even when the conceived extra cost is very high 10-30 cents/lb; however, income, race, and the state where a consumer lives were significant determinants in their WTP. It is possible, if not likely, that the even higher number or respondents would have indicated their willingness to purchase bacteriophage-treated foods (and the impact of the income, race, and the state factors may have also changed) if the costs presented to them were more realistic (1–5 cents/lb). Additional, larger scale surveys can address those possibilities, but our study provides a very strong preliminary data that should support the implementation of the bacteriophage technology in the real life fresh produce operations, as natural means for further improving the safety of fresh produce.

Materials and Methods

Survey methods and data

The dataset for the analysis reported in this study was obtained through a survey questionnaire administered by telephone to randomly selected consumers in 4 different states (Alabama, Georgia, North Carolina, and South Carolina) in the summer of 2010. These states were specifically selected due to their strong fresh produce industry and association of produce grown in these states with the recent outbreaks. The survey questionnaire was structured in 3 sections: Section 1 focused on problem introduction, thus respondents were questioned on their awareness of fresh produce contamination in the United States, the commonality in their opinion of how consumers become sick from eating fresh produce contaminated with harmful bacteria. Also, respondents were asked to identify where they thought the source of contamination was; be it at the farm, food distribution centers, grocery stores or processing plants. Section 1 also elicited information on respondents' routine behavior before consumption of fresh produce; whether they washed them with water or chemical food sanitizers and the effectiveness of their cleansing methods in ridding bacterial contamination on fresh produce. Respondents were also asked about the use of chemical food sanitizers as a cleansing tool and their thoughts on them eventually being harmful to humans and the environment. Lastly in section 1, respondents were questioned on their awareness of the bacteriophage technology as a means of reducing growth bacteria on fresh produce.

Table 5 A cross tabulation of incomes by WTP

Are you willing to pay extra for fresh produce that have been treated using the proposed technology?	What is the approximate total family/household income per year?					
	<$10,000	$10,001–$25,000	$25,001–$50,000	$50,001–$75,000	>$75,000	Total
No	3.1%	44.0%	30.2%	18.3%	4.4%	100.0%
Yes		17.9%	23.1%	43.6%	15.4%	100.0%
Don't Know			66.7%	33.3%		100.0%
Total	2.4%	36.7%	30.9%	23.8%	6.2%	100.0%

Table 6. Estimated results of the logit model

Variable	Estimate	Standard Error	Pr > ChiSq
Intercept	−3.634***	0.844	0.000
College	−0.305	0.384	0.428
Income	0.862***	0.194	0.000
White	0.728*	0.409	0.075
Female	0.063	0.382	0.870
Georgia	−1.054**	0.498	0.034
North Carolina	−0.885*	0.473	0.062
South Carolina	−0.976	0.613	0.111
Log-likelihood	−96.102		

Note: *,**, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

Table 8. Marginal effects corresponding to the logit model estimates

Effect		Point Estimate	Z Statistic	P>Z
College		−0.044	−0.80	0.425
Income		0.126***	5.24	0.000
White		0.107*	1.82	0.069
Female		0.009	0.16	0.870
Georgia	GA vs AL	−0.155**	−2.19	0.029
North Carolina	NC vs AL	−0.130*	−1.92	0.055
South Carolina	SC vs AL	−0.143	−1.62	0.105

Note: *,**, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

Section 2 provided a brief but precise description of the proposed bacteriophage technology as a food preservative. This description was constructed in a manner to ensure that respondents were educated fully on the science of the bacteriophage technology without it being too scientific and mundane in its terminology, thus maintaining respondents' high level of cooperation and interest in the survey questionnaire to produce accuracy in their response. In addition to the description of the bacteriophage technology, section 2 also elicited from respondents, their level of concordance with the use of biocontrol agents to ensure food safety; their reservations on the technology leaving residues on fresh produce and it possibly being harmful to humans and the environment; and the effectiveness of the bacteriophage technology in reducing the growth of bacteria on fresh produce than general chemical sanitizers currently being utilized by the industry. Respondents were then questioned on whether they would patronize fresh produce treated with bacteriophage. Lastly, this section solicited from the respondents their willingness to pay (WTP) extra for fresh produce treated with the proposed technology. Respondents who answered in the affirmative on their WTP, were asked to indicate how much more than the current price they would be willing to pay by expressing them in the following percentages: <5%, 6-10%, 11-15%, 16-20%, or > 20%.

Section 3 of the survey questionnaire obtained information on the demographics and socio-economic factors of the respondents (i.e., gender, age, race/ethnicity, education, marital status, household formation, income of household, and finally their State of residence). Income of household was approximated in the following, (<$10,000; $10,001-$25,000; $25,001-$50,000; $50,001-$75,000 and >$75,000) to capture all levels of income for the respondents. In addition, SAS software was utilized for data input and analysis for this study. Also, in this study, as in other WTP studies,[17] a binary logit model was employed to estimate consumers' WTP for an additional amount for fresh produce treated with bacteriophage technology.

Empirical model

Analyses of survey rankings in empirical work commonly utilize logit models.[17] The logit model was selected as the analytical method in this analysis because its asymptotic characteristics constrain the predicted probabilities to a range of 0 to 1. The logit model is commonly used in settings where dependent variable is binary.[33] Because the data source provided individual, rather than grouped, observations, the common estimation method of choice was the maximum likelihood.[34] Among the beneficial characteristics of maximum likelihood estimation are its consistent and asymptotically efficient parameter estimates.[35]

The empirical model assumes that the probability of observing willingness-to-pay an additional amount for bacteriophage treated fresh produce, P_i is dependent on a number of independent variables (X_{ij}) associated with consumer i and variable j, and a number of unknown parameters β. The likelihood of observing the dependent variable was tested as a function of variables that included education, income, race, location, and gender.

$$P_i = F(Z_i) = F\left(\alpha + \beta X_{ij}\right) = 1/[1 + exp(-Z_i)] \qquad (1)$$

where: F (Z_i) = Cumulative density function of probabilities, expressed as function of Z_i; P_i = the probability that an individual would be willing to pay an additional amount, which is at least 5 percent more than the current price for bacteriophage treated fresh produce; α = Intercept.

And βX_i is a linear combination of independent variables such that

$$Z_i = \log\,[P_i/(1-P_i)] = \beta X_i = \beta_0 + {}_{1\times 1} + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \qquad (2)$$

where: i = 1, 2,. .., n are observations Z_i = the log odds of choice for the ith observation X_n = the nth explanatory variable for the

Table 7. Odds ratios corresponding to the logit model estimates

Effect		Point estimate	95% Wald Confidence limits	
College		0.737	0.346	1.266
Income		2.368***	1.620	3.463
White		2.071*	0.928	4.621
Female		1.015	0.477	2.163
Georgia	GA vs AL	0.340**	0.127	0.908
North Carolina	NC vs AL	0.405*	0.159	1.031
South Carolina	SC vs AL	0.373	0.112	1.244
Loglikelihood		−96.101		

Note: *,**, and *** denote statistical significance at the 0.10, 0.05, and 0.01 levels, respectively.

i^{th} observation β = the parameters to be estimated; and ε = the error term.

The dependent variable Z_i, in the above equation is the logarithm of the probability that a particular choice will be made. The marginal effect of each independent variable (j) on the probability that the individual (i) is willing to pay an extra amount can be approximated by the partial derivative, $\delta P_i/\delta X_{ij}$. However, when the independent variables are categorical in nature as is the case with most of the explanatory variables in our model, $\delta P_i/\delta X_{ij}$ does not exist in that X_{ij} is discrete, which means that it does not vary continuously. In this case, probability changes must be obtained by evaluating P_i at the alternative (discrete) values of X_{ij}. Hence, the marginal effects are calculated as;

$$(\delta P_i/dX_{ij}) = P_i(WTP_i: X_{ij} = 1) - P_i(WTP_i: X_{ij} = 0). \quad (3)$$

The following model was developed to predict the likelihood that a participant would be willing to pay an additional 5 percent or more for bacteriophage treated fresh produce. The logit model expresses consumers' WTP as a function of income, education, gender, race, and States (Georgia, North Carolina, South Carolina, with Alabama being the reference state).

$$WTP_{Bacteriophage} = \beta_0 + \beta_1 College + \beta_2 Income + \beta_3 White + \beta_4 Female + \beta_5 Georgia + \beta_6 North\ Carolina + \beta_7 South\ Carolina + u \quad (4)$$

where: $WTP_{Bacteriophage} = 1$ if the individual was willing to pay at least an additional 5 percent more than the current price for bacteriophage treated fresh produce and 0 otherwise; College = 1 if the highest level of education attained by the individual is College and 0 otherwise; Income was coded as follows; = 1 if income <\$10,000 = 2 if income \$10,001–\$25,000 = 3 if income \$25,001–\$50,000 = 4 if income \$50,001–\$75,000 = 5 if income >\$75,000 White = 1 if the individual was of Caucasian race, and 0 otherwise; Female = 1 if the individual is female, and 0 otherwise; Georgia = 1 if the individual lives in Georgia, and 0 otherwise; North Carolina = 1 if the individual lives in North Carolina, and 0 otherwise; South Carolina = 1 if the individual lives in South Carolina, and 0 otherwise.

Conclusions

As the share of fresh produce in the United States food supply chain continues to increase, additional research will allow food marketers to target specific consumer segments that are willing to pay a premium for bacteriophage treated fresh produce. The results of this study suggest that a significant amount of consumers would be willing to pay an additional amount for bacteriophage-treated fresh produce over conventional ones. In addition, we discovered that certain demographic and socio-economic characteristics impact the willingness-to-pay (WTP) for bacteriophage treated fresh produce. From the findings, we can construct a profile of households most likely to purchase bacteriophage treated fresh produce at a premium price. Specifically, higher- earning households would be more likely to exhibit a higher willingness to pay for bacteriophage treated fresh produce at a 5 percent increase in price. Also, our findings show that Caucasians are most inclined to patronize premium priced fresh produce treated with bacteriophage relative to other races. Furthermore, our results show that the state where consumers live may affect their WTP, with residents of Georgia and North Carolina being less willing to pay an additional amount for bacteriophage treated fresh produce, relative to consumers in Alabama. This may be a reflection of perceptions and/or awareness of the proposed technology and of preventive additives in general.

Together, each of the significant variables, exclusive of education and gender, create a consistent picture of the characteristics of households that patronize bacteriophage treated fresh produce. All in all, areas in which the local economy consists of higher income households may be most successful target areas for bacteriophage treated fresh produce growers. A highly developed consumer market in suburban areas surrounding major US cities may offer the highest concentration of consumers who are most likely to patronize premium priced fresh produce treated with bacteriophage technology. This analysis may be the first of its kind; however, it provides an initial introduction to the bacteriophage treated fresh produce for a rapidly changing agricultural sector in regions with higher income levels in the country. As bacteriophage technology expands, public perception and awareness may change as well, thus the identification of consumer characteristics that influence the likelihood of willingness-to-pay for bacteriophage treated fresh produce will be invaluable as the market continues to grow.

Disclosure of Potential Conflicts of Interest

Alexander Sulakvelidze holds an equity stake in Intralytix, Inc.., a Maryland corporation involved with the development of phage preparations for various food safety and other applications.

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