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Research Article

Food Integrity and Food Technology Concerns in Canada: Evidence from Two Public Surveys

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Food integrity and food technologies both generate public concerns. There is little research to show the interactions between those concerns in particular samples, especially in Canada. In this paper, data from two national online samples are used to examine an aggregate of food integrity concerns, genetic modification in food, and food nanotechnology concerns in the Canadian public. A variety of trust, health, environmental, and science attitude variables are used to help explain the concerns that vary across the population. In addition, the food integrity concerns are tested as explanatory variables in the technology concern models to establish whether there is a strong or weak link between the two. Tobit and ordered probit regressions are used to model the variables for each of the survey samples. Results are examined to see if they are consistent across surveys and also consistent with an earlier study that was done in Australia. The results suggest that trust in people and trust in a variety of agents within the food system are beliefs that ameliorate concerns about food integrity and the two technologies. However, trust in advocacy organizations appears to be related to higher concerns in each case. Fundamentally and similar to the earlier Australian study, positive scientific attitudes are a major determinant of reduced concerns about food integrity and the two technologies.

1. Introduction

Technology applications remain contentious in the food industry globally. Unfortunately sometimes public concerns about technology applied to food may impede the ability of the food system to actually enhance its integrity through innovation. Public concern about genetically modified (GM) foods could discourage the use of genetic technologies for traceability, for example, since food industry participants may worry that the use of any technology is risky. Some issues related to food integrity (e.g., concerns about pesticides or chemical residues) may arise from concerns about potential impacts on consumer health, but concerns about the uses of technology may arise from worry about environmental implications. There is also a possibility that the existence of food integrity issues could be a reason for public concerns about the uses of technology related to food. It is also unknown whether the concerns about specific food technologies have the same explanatory influences (e.g., nanotechnology versus GM technology). Regardless of whether the factors that characterize concerns about food integrity are the same or different from the factors that characterize concerns about GM (nanotechnology), food technologies remain largely unexplored across time and across countries. Research in this area could inform food industry decision making about appropriate methods to enhance food integrity and about how much to focus on food integrity implications when introducing new technology applications.

Using data from two national online surveys (1800 people each) conducted in Canada, this study examines the influences on a broad class of general concerns about food integrity and the potential direct and indirect effects of those concerns on specific concerns about GM foods and nanotechnology applications in food products. In addition to the predictors (environmental and health concerns and attitudes towards science and technology) included in an earlier paper by Mohr and Golley [1], other variables that have been shown to influence consumer purchase behaviour and acceptance of food technologies are included in the analysis. These include sociodemographic characteristics such as income [2],

whether or not a respondent is French (Canada specific context, [3]), religious behaviour [4], and institutional trust [5]. Earle [6] identified the role of relational trust and calculative trust (in terms of risk management) and each of those should be considered when identifying how trust influences food product acceptance or concerns. There are a number of studies that have already examined the role of trust in terms of nanotechnology and those substantiate the need to include trust variables in the analysis. For example, Matin et al. [7] examined the effect of environmental attitudes and the fear of novel technologies (food technology neophobia) on consumer's acceptance of nanotechnology in general and its application in the food industry in Canada. The study found that food technology neophobia had a stronger effect on the support for nanotechnology than did environmental attitudes. Roosen et al. [8] examined the relationship between trust and willingness to pay (WTP) for functional food attributes introduced with nanotechnology among a sample of respondents in Canada and Germany. The study found that higher levels of trust reduced the perceived relative risk of nanotechnology and resulted in higher WTP for the foods. Siegrist et al. [9] found that social trust in the food industry influenced people's willingness to buy nanotechnology products.

This paper extends the research on food integrity by exploring the linkages between food integrity concerns and two technology applications in food. We examine a wider set of predictors than did Mohr and Golley's [1] study, using different methods. We also look at multiple technologies. This allows us to assess whether the relationship between food integrity concerns and concerns about technological applications is technology-specific. Based on the results of this study, we are able to assess whether or not the conclusions of Mohr and Golley [1] are applicable in different contexts (i.e., Canada in this case) as well.

2. Literature Review

Improved food integrity enhances food safety, authenticity, and quality and increases consumer trust in product claims and brand integrity [16]. Concerns about food integrity differ by product and production system [2]. As evident from the reported cases of food scandals (e.g., horse meat scandal in 2013), infractions on food integrity can have far-reaching implications for all food chain stakeholders. According to the Elliot Review, food integrity is ensuring that food which is offered for sale or sold not only is safe and of the nature, substance, and quality expected by the purchaser but also captures other aspects of food production, such as the way it has been sourced, procured, and distributed and being honest about those elements to consumers (HM Government, p. 84 [17]). To a large extent, this definition highlights the central role of consumers (as end users) with regard to food integrity. It also suggests that the focal point of the assurance of food integrity is the regulation of human activities in all aspects of food production, from farm to plate. Stated in this way, there is the potential for the predictors of concerns about food integrity to be conflated with concerns about specific applications of food technologies deemed as direct and conscious human interventions in food products and processes. This may be particularly important in the application of biotechnologies such as genetic modification and in the case of food products with highly desirable credence attributes [18]. If the predictors of food integrity are markedly different from those of specific technology applications in food, then the notion that the underlying casual factors are linked to general consciousness about the human intervention in food systems is not supported [1, 4]. Conversely, if the factors that influence food integrity are similar to those that affect the concerns about applications of these technologies, then the measures that improve food integrity standards and consumer confidence in these standards can also influence the acceptance of these technologies. Researchers have looked at many aspects of food integrity: food safety and quality assurance [2, 19–23], supply chain management [16, 24–26], and so forth. Other studies have examined the issue of food integrity in the context of specialized foods (see [18]). However, not much has been done to evaluate the linkage between food integrity concerns and concerns about biotechnology applications in food. Mohr and Golley (2015), in a study conducted in Australia, found evidence to suggest that concerns about genetically modified (GM) food content are affected by food integrity concerns and the factors that influence these concerns. The authors concluded that predictors of GM concerns are not uniquely distinguishable from more generalized concerns about food ingredients and products. Mohr and Golley [1]'s analysis did not, however, account for all of the factors such as trust and specific sociodemographic characteristics, which have been shown to influence consumer acceptance. Whether or not the identified linkages will hold in the case of different technological applications such as foods made with ingredients that are produced with nanotechnology is also unknown. Given the evidence of product specificity as it relates to food integrity [2], it is plausible that these linkages, if they do exist, may differ from one technology to another and may also vary by specific food item (although we do not examine that in this study).

3. Conceptual Model

Following the model specification identified in Mohr and Golley [1], we hypothesize that a set of variable categories including science benefit attitudes, environmental concerns, and health engagement may influence each of food integrity concerns and concerns about the application of specific technologies in food production or processing. Mohr and Golley [1] also included Intuitive Thinking from the Rational Experiential Inventory as a category of explanatory variable but such data was not collected in the Canadian surveys (due to length of survey). However, we also hypothesize the potential influence of variables such as general (relational) and institutional (calculative) trust, sociodemographic characteristics, and self-assessed science and environmental knowledge as having potential explanatory power. The conceptual model is described in Figure 1.

In defining the food integrity concern variable, respondents were asked to rate the health risks (on a scale from

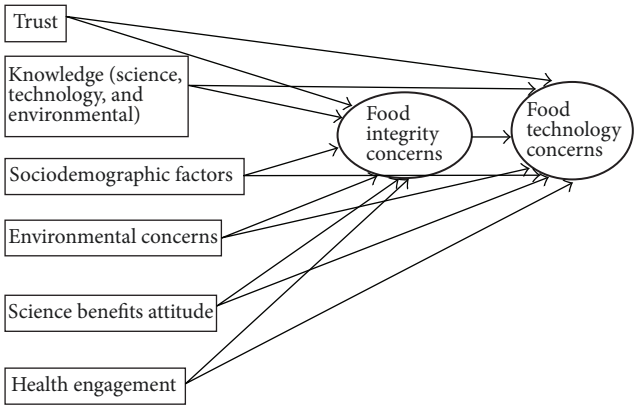

Figure 1: Hypothesized model of factors predicting influences of food integrity concerns and concerns for the food product of technology.

1, very low risk, to 5, very high risk) of the regular consumption of the following: (i) foods with pesticide or other chemical residues, (ii) *genetically modified* (GM) *food*, (iii) meat/fish/dairy products with hormone residues, (iv) *foods made with ingredients that are produced with nanotechnology*, and (v) meat/fish/dairy products with antibiotic residues. Food integrity concern is the average of responses to issues (i), (iii), and (v) (principal component factor analysis yielded one factor for both data sets and the Cronbach's alpha values are both above 0.8, which shows that there is good internal consistency between the three items used to measure food integrity concerns). This list of food integrity issues is not exhaustive (and notably does not include food fraud issues which had received relatively little attention in the Canadian press in the months leading up to the surveys) (December 2016 and January 2017). Concerns about GM refer to (ii), while concerns about nanotechnology refer to (iv). However, the set of issues is similar to the issues described by Mohr and Golley [1] who also did not include food fraud issues. Different from the 2016 study were the inclusion of hormones and antibiotics in livestock products (recently and increasingly important) and the exclusion of microbial contamination (which in the past we have found caused some confusion in similar general population surveys in Canada). Mohr and Golley [1] included food additives, preservatives, and colouring which are excluded from this analysis. (Models were estimated with foods enriched with vitamins and minerals and preservatives and/or artificial colouring included as part of food integrity concerns and results are similar to the ones reported in this paper.)

The sociodemographic explanatory variables that are included in the models include age, education (years), income, sex (male), whether the respondent answered the survey in French, whether the respondent lives in a city (as opposed to a town or rural environment), whether the respondent is the regular household grocery shopper, how frequently (including never) respondents attend a place of worship (church), and whether the respondent has relatives that live on a farm or ranch (farm).

Trust is defined in two components in the survey, the first using a General Trust question [11] which accounts for whether you generally trust other people or not. The second component of trust refers to a series of individual agents (trust in. . .that are responsible for food; see Table 1). These are aggregated into four individual or groups of agents including industry (the average of trust in farmers, processors, pharmaceutical companies, and retailers), advocacy groups (the average of consumer advocacy groups, environmental advocacy groups, and animal welfare advocacy groups), and individual trust in government and in universities/research organizations. Self-assessed science and environmental knowledge are assessed using a ten-point scale in each case by statements as follows: in general, to what extent do you feel knowledgeable about science and technology development/environmental problems?

Health engagement is measured using a scale from Roininen et al. [15] and the scale attempts to capture attention to health eating with a series of negative and positive described statements (see Table 1) (the negative statements described are reverse-coded and the overall health engagement variable is included as the sum of all statement scores).

Environmental concerns are measured using the myths of nature (Steg and Sievers [13]) and the New Human Interdependence Paradigm scale [12]. The NHIP scale [12] addresses the interdependence of humans' use of nature (anthropogenic view) and nature's intrinsic value (ecocentric view). In other words, the NHIP construct assumes that human development and conservation of nature are not mutually exclusive. The NHIP includes five Likert-type items which attempt to measure beliefs about the usefulness of nature and the intergenerational effects of the current utilization of natural endowments. Two different environmental concern variables are included because they describe different aspects of environmental attitudes and either could have relevance for the issues being considered.

4. Empirical Methods

Tobit regression models are used to estimate the factors that influence consumers' concerns about food integrity, since the dependent variable might be censored (not normally distributed). Ordered probit models are used to estimate the factors that influence consumers' concerns about GMO's and nanotechnology (each of which is described by distributions of scores from 1 through 5). The regression models are estimated in OxMetrics 6. Explanatory variables for the Tobit regression models include trust, self-rate knowledge of science and technology and environmental problems, trust, science benefit attitudes, environmental concerns, and health concerns. In addition to the explanatory variables included in the Tobit regressions, food integrity concerns are included as an explanatory variable in the ordered probit regressions.

5. Data

Data were collected from online surveys in Canada in December 2016 and January 2017. The surveys were targeted

Table 1: Questions used to measure variables.

	Questions	Source
Concerns about food issues	How do you rate the health risks of regular consumption of the following: (i) Foods with pesticide or other chemical residues (ii) Genetically modified (GM) food (iii) Meat/fish/dairy products with hormone residues (iv) Foods made with ingredients that are produced with nanotechnology (v) Meat/fish/dairy products with antibiotic residues Responses are as follows: 0, do not know; 1, very low risk; . . . 5, very high risk	
Frequency of attending service at place of worship	In the past year, how often have you attended a regular service at a place of worship? 0, prefer not to say; 1, never; . . . 5, regularly (once per week)	
Frequency of grocery shopping	How often are you involved in the regular grocery shopping for your household? Responses are as follows: 1, never; . . . 5, always	
Farm	Do you, or someone you are related to, own or work on a ranch or farm? 0, no; 1, yes	
Knowledge (1) Self-rated knowledge of science and technology developments	In general, to what extent do you feel knowledgeable about scientific and technological developments? 1 means that "you have little knowledge" and 10 means that "you know a lot"	
Knowledge (2) Self-rated knowledge of environmental problems	To what extent do you feel knowledgeable about environmental problems? 1 means that "you have little knowledge" and 10 means that "you know a lot"	
Science benefit attitude	All things considered, would you say that the world is better off, or worse off, because of science and technology? 1 means that "the world is a lot worse off" and 10 means that "the world is a lot better off"	Vandermoere et al. [10]
Trust (1) Generalized trust in people	Generally speaking, would you say that most people can be trusted? 1, (most) people can be trusted; 0, cannot be too careful in dealing with people or do not know	Glaeser et al. [11]
Trust (2) Trust in institutions responsible for food	How much trust do you have in the following groups or institutions regarding their responsibility for food production in Canada? Responses are anchored as follows: 1, no trust; 5, absolute trust. The organizations are farmers, food processors or manufacturers, research organizations or universities, pharmaceutical industry which provides drugs to treat animals, government agencies or public authorities, retailers, advocacy consumer organizations, advocacy environmental organizations, and advocacy organizations for animal welfare	Roosen et al. [8]
Knowledge (1) Self-rated knowledge of science and technology developments	In general, to what extent do you feel knowledgeable about scientific and technological developments? 1 means that "you have little knowledge" and 10 means that "you know a lot"	
Knowledge (2) Self-rated knowledge of environmental problems	To what extent do you feel knowledgeable about environmental problems? 1 means that "you have little knowledge" and 10 means that "you know a lot"	
Science benefit attitude	All things considered, would you say that the world is better off, or worse off, because of science and technology? 1 means that "the world is a lot worse off" and 10 means that "the world is a lot better off"	Vandermoere et al. [10]
Environmental concerns (1) New Human Interdependence Paradigm (NHIP) scale (sum)	(i) Human beings can progress only by conserving nature's resources (ii) Human beings can enjoy nature only if they make wise use of its resources (iii) Human progress can be achieved only by maintaining ecological balance (iv) Preserving nature at the present time means ensuring the future of human beings (v) We must reduce our consumption levels to ensure well-being of the present and future generations Responses are 1, strongly disagree; . . . 5, strongly agree	Corral-Verdugo et al. [12]

Table 1: Continued.

	Questions	Source
Environmental concerns (2) Myths of nature (dummy variables)	Please indicate which one of the following statements corresponds most with your view on nature. Select one only. *Myth of nature 1*: environmental problems can only be controlled by enforcing radical changes in human behaviour in society as a whole (nature ephemeral) *Myth of nature 2*: environmental problems are not entirely out of control, but the government should dictate clear rules about what is and what is not allowed (nature perverse/tolerant) *Myth of nature 3*: we do not need to worry about environmental problems because, in the end, these problems will always be resolved by technological solutions (nature benign) *Myth of nature 4*: we do not know whether environmental problems will magnify or not (nature capricious)	Steg and Sievers [13]
Health engagement-general health interest (sum)	Please respond to the following statements: (i) *The healthiness of food has little impact on my food choices (ii) I am very particular about the healthiness of food I eat (iii) *I eat what I like and I do not worry much about the healthiness of food (iv) It is important for me that my diet is low in fat (v) I always follow a healthy and balanced diet (vi) It is important for me that my daily diet contains a lot of vitamins and minerals (vii) *The healthiness of snacks makes no difference to me (viii) *I do not avoid foods, even if they may raise my cholesterol Responses are anchored as follows: 1, strongly disagree; . . . 5, strongly agree	Roininen et al. [14, 15]

Note. ∗ implies that the statement was reverse-coded for the analysis.

Table 2: Frequency distribution of ratings of concern about potential issues of food integrity: 2016 sample ($N = 1795$).

	Response					
	Do not know	Very low risk	Low risk	Moderate risk	High risk	Very high risk
	0	1	2	3	4	5
Foods with pesticide or other chemical residues	95 (5.3)	26 (1.5)	125 (7.0)	469 (26.1)	464 (25.9)	616 (34.3)
Meat/fish/dairy products with hormone residues	159 (8.9)	41 (2.3)	236 (13.2)	606 (33.9)	404 (22.6)	343 (19.2)
Meat/fish/dairy products with antibiotic residues	149 (8.3)	43 (2.4)	228 (12.7)	629 (35.1)	436 (24.3)	309 (17.2)
Genetically modified (GM) food	187 (10.3)	136 (7.5)	265 (14.5)	520 (28.5)	366 (20.1)	348 (19.1)
Foods made with ingredients that are produced with nanotechnology	627 (34.4)	90 (4.9)	251 (13.8)	442 (24.3)	241 (13.2)	171 (9.4)

Note. Percentages in parentheses (%).

to people who are at least 18 years of age who normally buy groceries for their households. The survey questionnaires covered different issues related to food and technologies. The questions used in this analysis are identical between the two surveys and they were used in a number of previous questionnaires (some since 2006 and others since 2012).

The statements on potential food issues included the possibility of answering do not know about each issue. This reduced the overall sample size from the 1800 respondents to over 1600 for food integrity/GM. However, since many more people answered "do not know" to the question about nanotechnology in each survey, the data sets for nanotechnology in each survey were significantly smaller. Thus the data sorting resulted in four samples, that is, two for food integrity and GM (2016 and 2017) and two for nanotechnology (2016 and 2017).

Data showing the distribution of responses to the statements aggregated to food integrity concerns and to the individual GM and nanotechnology concerns are shown in Table 2 (2016) and Table 3 (2017). The distributions show that the survey respondents find the possibility of pesticides or chemical residues as extremely risky and that the risks of hormones and antibiotic residues centre around moderate risks (for both surveys). Concerns about GM and nanotechnology also centre around perceived moderate risks, although the numbers highlight the very low level of knowledge about nanotechnology. It is interesting that Mohr and Golley [1] with a different question (how concerned are you about. . .) found

Table 3: Frequency distribution of ratings of concern about potential issues of food integrity: 2017 sample (N = 1814).

	Response					
	Do not know	Very low risk	Low risk	Moderate risk	High risk	Very high risk
	0	1	2	3	4	5
Foods with pesticide or other chemical residues	93 (5.1)	33 (1.8)	125 (6.9)	404 (22.3)	492 (27.2)	663 (36.6)
Meat/fish/dairy products with hormone residues	141 (7.8)	37 (2.0)	208 (11.5)	600 (33.1)	478 (26.4)	349 (19.2)
Meat/fish/dairy products with antibiotic residues	134 (7.4)	48 (2.7)	232 (12.8)	589 (32.6)	453 (25.0)	353 (19.5)
Genetically modified (GM) food	170 (9.5)	140 (7.8)	283 (15.8)	514 (28.7)	336 (18.8)	346 (19.3)
Foods made with ingredients that are produced with nanotechnology	554 (30.9)	93 (5.2)	260 (14.5)	460 (25.6)	241 (13.4)	186 (10.4)

Note. Percentages in parentheses (%).

that, in general, Australian responses were at the "extremely concerned" end of the scale for almost all of the issues including pesticides, additives, preservatives, and colourings.

The summary statistics for the variables that are included in the regression analysis are provided in Table 4. In terms of demographic characteristics of respondents, the samples are similar in terms of the language used by the respondent to respond to the survey (French or English), percent of males, age of the respondent, education level attained by the respondent, location of respondent (city, town, or rural) habitation, ownership or employment at a farm by the respondent or his/her relatives, and household income. The samples are also similar in terms of average scores for concerns about nanotechnology and GM, trust in the food industry, and the NHIP scale. There are small differences in the other variables related to consumer attitudes, concerns, knowledge, and behaviour.

6. Empirical Results

Results from the Tobit and ordered probit regressions are summarized in Table 5. In Table 6, results are reported for marginal effects of explanatory variables on the probability of the respondent stating that regular consumption of GM or nanotechnology has a very high risk. For Tobit models, since there are limited to no censored values, the coefficients are the marginal effects of the explanatory variables on the expected value of the dependent variable [27] (in this case food integrity concern).

(i) Food Integrity Concern. Respondents who generally trust people are less likely to be concerned about food integrity, which was expected (marginal effects are −0.08 and −0.12 in 2016 and 2017, resp.). Trust in groups or institutions that are responsible for food significantly influences food integrity concerns. Marginal effect results show that trust in the government reduces food integrity concerns for respondents (marginal effects are −0.14 in 2016 and −0.09 in 2017). Trust in the food industry also reduces food integrity concerns with marginal effects being −0.17 in 2016 and −0.22 in 2017. Trust in research organizations/universities increases food integrity concerns in 2016 and the marginal effect (0.06) is lower than the marginal effects of trust in other groups/institutions on food integrity concern. The relationship between trust in research organizations/universities and food integrity concerns is not significant in 2017. On the contrary, trust in advocacy groups increases food integrity concerns (marginal effects are 0.16 in 2016 and 0.21 in 2017).

Environmental concerns influence food integrity concerns. The New Human Interdependence Paradigm scale is positively related to food integrity concern and marginal effects are 0.05 in 2016 and 0.03 in 2017. The relationship between the different myths of nature and food integrity concerns has opposite signs between the 2016 and 2017 surveys. Compared to people who agreed that they do not know whether environmental problems will magnify or not (nature capricious, myth of nature 4), respondents who agreed that environmental problems can only be controlled by enforcing radical changes in human behaviour in society as a whole (nature ephemeral, myth of nature 1) are less likely to be concerned about food integrity in 2016 (marginal effect = −0.14), while they are more likely to be concerned about food integrity in 2017 (marginal effect = 0.31). In addition, respondents who agreed that environmental problems are not entirely out of control but the government should dictate clear rules about what is and what is not allowed (nature perverse/tolerant, myth of nature 2) are less likely to be concerned about food integrity as compared to those respondents who agreed that we do not know whether environmental problems will magnify or not in 2016 but this relationship is not significant in 2017.

Health engagement interest increases food integrity concerns in both 2016 and 2017. This shows that people who are interested in eating healthily are more likely to be concerned with food integrity, which was expected (marginal effects are 0.04 and 0.03 in 2016 and 2017, resp.). Mohr and Golley [1] also found that health engagement positively influences food integrity concerns.

Self-rated knowledge of science and technology and environmental problems are not significantly related to food integrity concerns in both 2016 and 2017. People who have

Table 4: Summary statistics for variables included in the models.

	2016		2017	
	Food Integrity and GM subsample	Nanotechnology subsample	Food integrity and GM subsample	Nanotechnology subsample
Food integrity concern (0–5)	3.58 (1.00)	3.58 (0.98)	3.51 (1.00)	3.48 (0.98)
GM concern (1–5)	3.32 (1.21)	—	3.29 (1.23)	—
Nanotechnology concern (1–5)	—	3.13 (1.13)	—	3.13 (1.13)
Sociodemographic variables				
French	18.7%	18.5%	18.3%	17.7%
Age	45.5 (16.8)	44.6 (16.8)	46.2 (16.8)	45.1 (16.9)
Male	48.4%	51.3%	47.9%	50.5%
Presence of children < 18 years	19.4%	19.5%	18.0%	18.1%
Education	15.2 (1.99)	15.3 (1.96)	15.2 (1.98)	15.1 (2.00)
City	70.4%	70.5%	71.1%	71.5%
Church (0–5)	1.98 (1.39)	2.05 (1.42)	2.02 (1.43)	2.05 (1.43)
Farm	11.0%	11.0%	10.9%	11.3%
Income ($1,000.00)	77.7 (35.7)	76.7 (35.7)	77.7 (35.9)	76.6 (36.2)
Regular shopper (1–5)	4.44 (0.86)	4.41 (0.90)	4.39 (0.89)	4.37 (0.89)
Self-rated knowledge				
Knowledge of science and technology (0–10)	5.39 (2.36)	5.55 (2.36)	5.29 (2.35)	5.49 (2.35)
Knowledge of environmental problems (0–10)	5.82 (2.20)	5.90 (2.20)	5.78 (2.18)	5.85 (2.18)
Science benefit attitude (0–10)	7.12 (2.08)	7.05 (2.13)	6.95 (2.14)	6.92 (2.14)
Trust				
Generalized trust in people	49.9%	49.0%	46.9%	47.4%
Trust in government (1–5)	2.95 (1.05)	2.93 (1.07)	2.91 (1.01)	2.91 (1.02)
Trust in industry (1–5)	2.77 (0.75)	2.76 (0.77)	2.76 (0.70)	2.75 (0.71)
Trust in research organizations/universities (1–5)	3.37 (0.96)	3.34 (0.96)	3.34 (0.92)	3.31 (0.93)
Trust in advocacy groups (1–5)	2.90 (0.85)	2.88 (0.85)	2.86 (0.75)	2.83 (0.75)
Environmental concern				
NHIP (0–25)	20.1 (3.73)	19.9 (3.81)	19.7 (3.87)	19.5 (3.97)
Myth of nature 1	49.2%	49.4%	44.3%	42.6%
Myth of nature 2	39.3%	38.4%	41.0%	41.7%
Myth of nature 3	2.14%	2.26%	2.97%	3.47%
Myth of nature 4	8.94%	9.46%	10.9%	11.5%
Health engagement (0–40)	27.4 (5.17)	27.2 (5.15)	27.1 (4.95)	26.8 (4.84)
Sample size	1633	1195	1618	1240

Table 5: Regression results' concerns about GM and Nanotechnology.

	2016			2017		
	Food integrity concern	GM concern	Nanotechnology concern	Food integrity concern	GM concern	Nanotechnology concern
	β (T-statistic)					
Constant	2.08*** (7.65)	0.25 (0.71)	−0.71* (−1.78)	2.32*** (8.57)	0.29 (0.87)	0.10 (0.25)
Food integrity concern	—	0.69*** (21.0)	0.69*** (17.4)	—	0.81*** (23.9)	0.83*** (20.9)
Sociodemographic variables						
French	−0.08 (−1.38)	0.18** (2.39)	−0.01 (−0.09)	0.01 (0.19)	0.06 (0.83)	0.01 (0.06)
Age	0.005*** (3.27)	0.004** (2.09)	0.01*** (2.79)	0.01*** (3.60)	−0.001 (−0.40)	0.003 (1.58)
Male	−0.04 (−0.84)	−0.06 (−0.96)	−0.11* (−1.67)	−0.08* (−1.64)	−0.09 (−1.52)	−0.11 (−1.57)
Presence of children < 18 years	0.05 (0.84)	0.27*** (3.74)	0.12 (1.46)	0.08 (1.34)	0.04 (0.48)	−0.08 (−0.95)
Education	−0.004 (−0.29)	−0.03* (−1.68)	−0.01 (−0.59)	−0.02* (−1.69)	−0.04*** (−2.54)	−0.03* (−1.72)
City	0.07 (1.38)	0.14** (2.37)	0.04 (0.55)	0.03 (0.56)	−0.07 (−1.16)	0.11 (1.57)
Church	0.02 (1.00)	0.05** (2.35)	0.03 (1.45)	0.03* (1.68)	0.05*** (2.78)	0.05** (2.38)
Farm	−0.08 (−1.09)	−0.11 (−1.21)	0.03 (0.31)	0.01 (0.15)	−0.02 (−0.24)	−0.05 (−0.54)
Income	−0.0004 (−0.63)	−0.001 (−0.83)	−0.001 (−0.89)	−0.001 (−0.90)	−0.0001 (−0.07)	0.001 (0.60)
Regular shopper	−0.005 (−0.19)	−0.03 (−0.94)	−0.01 (−0.24)	0.02 (0.79)	0.01 (0.30)	−0.02 (−0.59)
Self-rated knowledge						
Knowledge of science and technology	0.01 (1.08)	−0.04*** (−2.75)	−0.02 (−1.10)	0.02 (1.28)	−0.05*** (−2.90)	−0.04** (−2.33)
Knowledge of environmental problems	0.003 (0.22)	−0.02 (−1.38)	−0.03 (−1.54)	0.02 (1.48)	−0.02 (−1.15)	0.02 (0.95)
Science benefit attitude	−0.05*** (−4.55)	−0.07*** (−4.37)	−0.07*** (−3.84)	−0.05*** (−3.83)	−0.10*** (−6.87)	−0.10*** (−6.10)
Trust						
Generalized trust in people	−0.08* (−1.70)	−0.14** (−2.40)	−0.19*** (−2.82)	−0.12*** (−2.47)	−0.02 (−0.27)	−0.06 (−0.85)
Trust in government	−0.14*** (−4.99)	−0.12*** (−3.55)	−0.13*** (−3.25)	−0.09*** (−3.11)	−0.15*** (−4.19)	−0.07* (−1.85)
Trust in industry	−0.17*** (−4.36)	0.04 (0.91)	0.22*** (3.83)	−0.22*** (−4.84)	0.08 (1.55)	0.04 (0.65)
Trust in research organizations/universities	0.06** (2.13)	−0.17*** (−4.42)	−0.19*** (−4.39)	−0.02 (−0.67)	−0.11*** (−2.70)	−0.20*** (−4.30)
Trust in advocacy groups	0.16*** (5.14)	0.17*** (4.27)	0.17*** (3.62)	0.21*** (5.15)	0.15*** (2.88)	0.16*** (2.86)
Environmental concerns						
NHIP	0.05*** (6.99)	0.01 (1.33)	0.01 (1.02)	0.03*** (4.83)	−0.01 (−0.74)	0.01 (0.59)
Myth of nature 1	−0.14* (−1.69)	−0.10 (−0.97)	−0.11 (−0.96)	0.31*** (3.84)	0.25*** (2.52)	0.01 (0.12)
Myth of nature 2	−0.31*** (−3.78)	−0.10 (−1.01)	−0.06 (−0.50)	0.12 (1.54)	0.18* (1.87)	0.06 (0.56)
Myth of nature 3	−0.15 (−0.90)	0.03 (0.15)	−0.02 (−0.07)	0.05 (0.32)	−0.01 (−0.03)	−0.13 (−0.67)

Table 5: Continued.

	2016			2017		
	Food integrity concern	GM concern	Nanotechnology concern	Food integrity concern	GM concern	Nanotechnology concern
	β (T-statistic)					
Health Engagement	0.04*** (8.83)	0.01** (2.31)	0.03*** (4.05)	0.03*** (6.19)	0.02*** (3.31)	0.01* (1.69)
$\mu 1$	—	0.93*** (18.1)	1.15*** (17.8)	—	1.06*** (18.8)	1.22*** (18.1)
$\mu 2$	—	2.07*** (33.2)	2.44*** (31.4)	—	2.25*** (33.4)	2.60*** (31.8)
$\mu 3$	—	2.93*** (41.6)	3.33*** (37.5)	—	3.08*** (41.0)	3.50*** (37.7)
Sigma	0.89*** (57.0)			0.91*** (56.7)		
Log-likelihood	−2120.3	−2075.1	−1475.0	−2147.5	−1986.1	−1473.0
Scaled R^2	—	0.43	0.43	—	0.50	0.49
Number of censored observations	1629	—	—	1612	—	—
Sample	1633	1633	1195	1618	1618	1240

***,**,* significant difference at the 1%, 5%, and 10% level.

positive science benefit attitudes are less likely to be concerned about food integrity as compared to those people who have negative attitudes and the marginal effect is −0.05 in both 2016 and 2017. Mohr and Golley [1] also found a negative relationship between science benefit attitudes and concerns about GM.

Demographic variables also influence concerns about food integrity. Respondents who attend service at a place of worship regularly are more likely to be concerned about food integrity in 2017 as compared to those who never attend or attend fewer times but the relationship between these two variables is not significant in 2016. Age increases food integrity concerns in both 2016 and 2017 (marginal effects are 0.005 in 2016 and 0.01 in 2017). Male respondents are less likely to be concerned about food integrity as compared to female respondents in 2017 (marginal effect = −0.08) but the relationship between the two variables is not significant in 2016. Language (1, French; 0, English), presence of children below 18 years of age, whether the respondent lives in a city, whether the respondent or his/her relative owns or works at a farm, household income, and frequency of grocery shopping do not significantly influence food integrity concerns.

(ii) Concerns about GM and Nanotechnology. Food integrity concerns significantly drive concerns about both GM and nanotechnology (marginal effects are 0.15 and 0.17 in 2016 and 2017, resp., for GM and 0.10 and 0.11 for nanotechnology in 2016 and 2017, resp.). This shows that the marginal effects of food integrity concerns on concerns for the two technologies are higher for GM than for nanotechnology (possibly explained by the lower level of awareness of nanotechnology in food). Mohr and Golley [14] also found a positive link between food integrity concern and concerns about GM food.

Respondents who generally trust people are less likely to be concerned about GM and nanotechnology (marginal effect = −0.03) in 2016 but the relationships between the two variables for both technologies are not significant in 2017. Trust in the government lowers concerns about GM foods and nanotechnology in both years. A one-unit increase in trust in government reduces the probability of a respondent stating that regular consumption of GM foods is a very high risk by 3% in both years. A one-unit increase in trust in the government reduces the probability of the respondent stating that the regular consumption of foods made with ingredients that are produced using nanotechnology is a very high risk by 2% in 2016 and 1% in 2017. Trust in the food industry increases concerns about nanotechnology in 2016 only (marginal effect = 0.03) but the relationship between trust in the food industry and concerns about GM is not significant in either year. Trust in research organizations or universities significantly reduces concerns about GM and nanotechnology in both years (marginal effects are −0.04 in 2016 and −0.02 in 2017 for GM and −0.03 for nanotechnology in both years). People who trust advocacy groups are more concerned about GM and nanotechnology in both years as compared to respondents who do not trust the groups (marginal effects are 0.04 in 2016 and 0.03 in 2017 for GM and 0.02 for nanotechnology in both years).

The New Human Interdependence Paradigm scale does not directly influence concerns about GM and nanotechnology but it does influence the concerns indirectly through the food integrity concerns. In 2017, people who agreed that environmental problems can only be controlled by enforcing radical changes in human behaviour in society as a whole (myth of nature 1) and those who agreed that environmental problems are not entirely out of control but the government should dictate clear rules about what is and what is not allowed (myth of nature 2) are more likely to be concerned about GM as compared to respondents who agree that we do not know whether environmental problems will magnify

Table 6: Marginal effects for concerns about food integrity, GM, and nanotechnology.

	2016		2017	
	GM concern	Nanotechnology concern	GM concern	Nanotechnology concern
Food integrity concern	0.15*** (17.4)	0.10*** (11.8)	0.17*** (18.1)	0.11*** (12.4)
Sociodemographic variables				
French	0.04** (2.26)	−0.001 (−0.09)	0.01 (0.82)	0.001 (0.06)
Age	0.001** (2.08)	0.001*** (2.74)	−0.0002 (−0.40)	0.0004 (1.58)
Male	−0.01 (−0.96)	−0.02* (−1.65)	−0.02 (−1.52)	−0.01 (−1.56)
Presence of children < 18 years	0.06*** (3.45)	0.02 (1.38)	0.01 (0.48)	−0.01 (−0.98)
Education	−0.01* (−1.68)	−0.002 (−0.59)	−0.01*** (−2.53)	−0.004* (−1.70)
City	0.03*** (2.44)	0.01 (0.55)	−0.02 (−1.14)	0.01 (1.62)
Church	0.01** (2.34)	0.005 (1.44)	0.01*** (2.77)	0.01** (2.36)
Farm	−0.02 (−1.27)	0.005 (0.30)	−0.004 (−0.25)	−0.01 (−0.56)
Income	−0.0002 (−0.83)	−0.0001 (−0.89)	−0.00001 (−0.07)	0.0001 (0.60)
Regular shopper	−0.01 (−0.94)	−0.001 (−0.24)	0.002 (0.30)	−0.003 (−0.59)
Knowledge				
Knowledge of science and technology	−0.01*** (−2.74)	−0.003 (−1.10)	−0.01*** (−2.89)	−0.01** (−2.30)
Knowledge of environmental problems	−0.005 (−1.37)	−0.004 (−1.53)	−0.004 (−1.15)	0.002 (0.95)
Science benefit attitude	−0.01*** (−4.33)	−0.01*** (−3.74)	−0.02*** (6.65)	−0.01*** (−5.66)
Trust				
Generalized trust in people	−0.03** (−2.39)	−0.03*** (−2.78)	−0.003 (−0.27)	−0.01 (−0.86)
Trust in government	−0.03*** (−3.52)	−0.02*** (−3.19)	−0.03*** (−4.14)	−0.01* (−1.84)
Trust in industry	0.01 (0.91)	0.03*** (3.72)	0.02 (1.55)	0.01 (0.65)
Trust in research organizations/universities	−0.04*** (−4.37)	−0.03*** (4.22)	−0.02*** (−2.68)	−0.03*** (−4.13)
Trust in advocacy groups	0.04*** (4.22)	0.02*** (3.53)	0.03*** (2.87)	0.02*** (2.81)
Environmental concerns				
NHIP	0.003 (1.33)	0.001 (1.02)	−0.001 (−0.73)	0.001 (0.59)
Myth of nature 1	−0.02 (−0.97)	−0.02 (−0.96)	0.05*** (2.47)	0.002 (0.12)
Myth of nature 2	−0.02 (−1.02)	−0.01 (−0.51)	0.04* (1.83)	0.01 (0.55)
Myth of nature 3	0.01 (0.15)	−0.002 (−0.07)	−0.001 (−0.03)	−0.02 (−0.74)
Health engagement	0.003** (2.30)	0.004*** (3.92)	0.004*** (3.28)	0.002* (1.68)

***,**,* significant difference at the 1%, 5%, and 10% level. The marginal effects reported are for the "very high risk" category.

or not (myth of nature 4). Health engagement increases concerns about GM in both years and nanotechnology in 2016 (marginal effects are 0.003 in 2016 and 0.004 in 2017 for GM and 0.004 in 2016 and 0.002 in 2017 for nanotechnology).

Self-rated knowledge of science and technology reduces concerns about GM in both years and nanotechnology in 2017 and marginal effects are all equal to −0.01. Self-rated knowledge of environmental problems does not significantly influence concerns about GM and nanotechnology. Positive science benefit attitudes reduce concerns about GM and nanotechnology in both years (marginal effects = −0.01 or −0.02). Mohr and Golley [1] also found a negative relationship between science benefit attitudes and concerns about GM content in food.

Demographic variables also influence concerns about GM and nanotechnology. People who regularly attend services at a place of worship are more likely to state that GM in both years and nanotechnology in 2017 (marginal effect = 0.01) have very high risks. Male respondents are more likely to have lower concerns about nanotechnology as compared to females (marginal effect = −0.02). Respondents who answered the survey in French are more likely to state that regular consumption of GM food is a very high risk in 2016 (marginal effect = 0.04). Age of the respondent is positively related to concerns about GM and nanotechnology in 2016 (both marginal effects are equal to 0.001) but the relationships between age of the respondent and concerns about the two technologies are not significant in 2017. Respondents who have children less than 18 years in the household are more likely to state that regular consumption of GM food is a very high risk (marginal effect = 0.06) but the relationships between presence of children in the household and concerns about GM in 2017 and nanotechnology in both years are not significant. One-year increase in the number of years of education attained by the respondent reduces the probability of the respondent stating that GM is a very high risk by 1% in both years and the probability of the respondent stating that nanotechnology is a very high risk by 0.4% but the relationship between education and concerns about nanotechnology is not significant for 2016. Respondents who live in cities are more concerned about GM than those respondents who live in towns and rural areas in 2016 (marginal effect = 0.03). However, the effect of where the respondent lives is not significant for GM in 2017 or for nanotechnology in either year. In this study, frequency of buying groceries, household income, and whether the respondent or his/her relative owns or works at a farm do not significantly drive concerns about GM and nanotechnology (except through some indirect effects from food integrity concerns).

7. Conclusions

The results confirm the findings of Mohr and Golley [1] that concerns about food integrity are directly related to more specific concerns about GM and nanotechnology applications for food. The marginal effect of food integrity concerns on the probability of the respondent rating the regular consumption of GM food as "very low risk" is −0.05 in both years, while it is 0.15 and 0.17 in 2016 and 2017, respectively, for the response "very high risk." The marginal effect of food integrity concerns on the probability of the respondent rating the regular consumption of foods with ingredients from nanotechnology as "very low risk" is −0.04 in both years, while it is 0.10 and 0.11 in 2016 and 2017, respectively, for the response "very high risk."

Belief in the benefits of science is associated with lower concerns about food integrity and both GM and nanotechnology applications in food (and this corresponds to Mohr and Golley [1]). Trust variables (both generalized trust and trust in different agent groups) had significant explanatory power for both food integrity concerns and for GM and nanotechnology, although notably trust in advocacy groups increases concerns and trust in people and other agents generally reduces concerns. Health engagement (as measured in this study) had significant and positive impacts on the levels of concern for most specifications of food integrity, GM, and nanotechnology applications. For the technologies considered, both of which have been shown by scientists to be "safe," this suggests that the concerns about specific technologies are similar to concerns about other food integrity issues. This finding, similar to the earlier Australian findings, suggests that attempts to show the safety of the use of new genetic and nanotechnologies have not been effective and the technologies are strongly related to broader concerns about food integrity. The impacts of demographic and other explanatory variables are somewhat inconsistent across the food integrity, GM, and nanotechnology issues.

Potential policy implications of the results include the fact that science understanding and positive attitudes towards science and technology are keys to alleviating concerns about food integrity (and the technologies). Increases in the level of those variables and the trust variables, specifically in the different agents within the food system, government, industry, and researchers, might reduce food integrity concerns (and their attendant costs when food integrity issues arise and the public reacts more strongly or for longer than the issue might warrant) and lead to lower levels of concern about the foods from new technologies. However, changing either of those sets of variables is complex and does not result from a knowledge deficit approach but requires transparency and engagement throughout the food industry to ensure that people's values are acknowledged and shared. With the understanding that working together throughout the food industry could improve food integrity attitudes as well as technology attitudes, the incentives for a whole of industry (government and public) approach are much higher.

Further research in this area could include testing of different explanatory variables, examination of different uses of technology, and different modeling approaches (e.g., a reattempt to undertake structural equation modeling). All of those approaches could enhance the robustness of the findings reported here.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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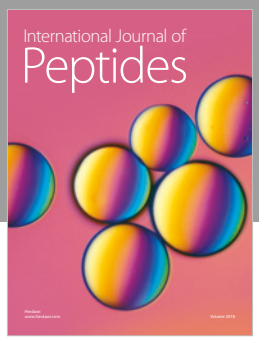

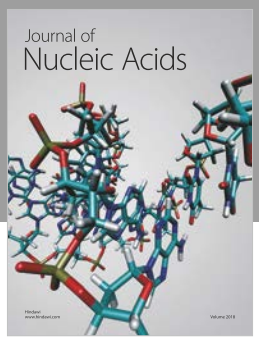

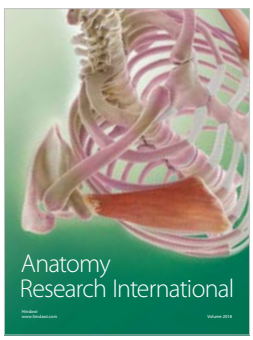

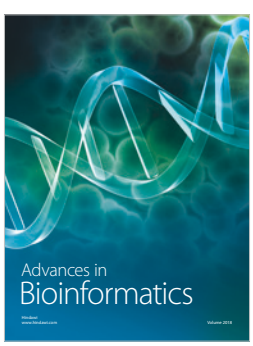

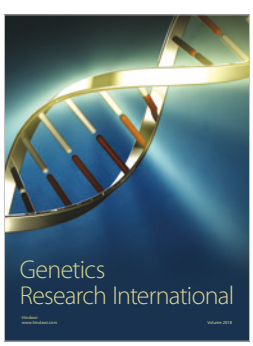

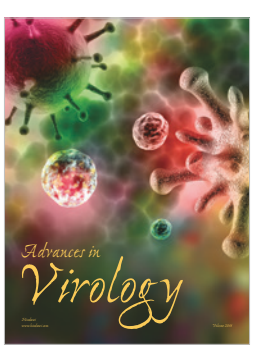

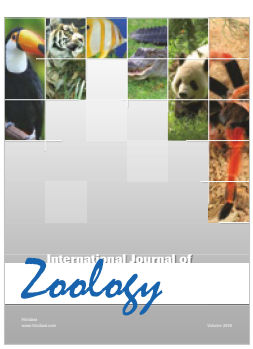

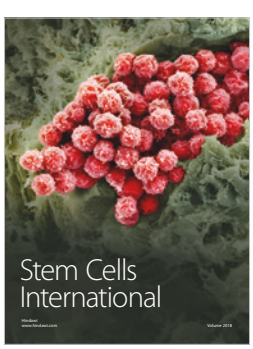

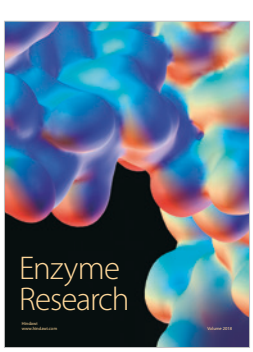

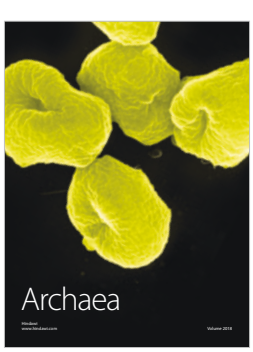


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