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Finding alternatives: Canadian attitudes towards novel foods in support of sustainable agriculture

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Global agriculture and farming practices account for roughly a quarter of total atmospheric emissions. Protein agriculture is especially prone to greenhouse gas emissions. There is a need to find alternatives for protein forms and sustainable practices in providing alternative protein sources. However, sustainable agricultural practices must consider consumer behaviour and attitude towards switching protein sources. In this quantitative study, a survey of 993 Canadians was carried out to better understand the likelihood of adoption of alternative proteins, cultured meat, insects and jellyfish; attitudes towards sustainable agriculture were also explored. Results show that novel foods that imitate traditional protein sources have a higher acceptance rate than those not part of the cultural food landscape. There is no evidence that consumers would switch from traditional protein sources when given more protein source options, calling into question the environmental efficacy of novel food offerings. This suggests that investment in alternative proteins as sustainable agriculture requires consumer engagement to see widespread success.

1. Introduction

Global agriculture and farming practices—including deforestation and the removal of carbon sinks and burning of fossil fuels—account for roughly a quarter of total atmospheric emissions (Garnier et al., 2019). When considering other factors in food production, such as the making of fertiliser and shipping of products and inputs, 35% of all atmospheric greenhouse gases (GHG) may be attributed to the globalised food chain (Vermeulen et al., 2012). Sans and Combris's (2015) longitudinal study found that global meat consumption almost doubled over 50 years, from "23.1 kg per person per year in 1961 to 42.20 kg per person per year in 2011" (p. 106). Consumer reliance on traditional sources of meat is a major contributor to agricultural GHG.

Important innovations in food production have yielded alternative protein sources while reducing the resources needed to produce food staples such as plant-based alternatives to meat, genetically engineered food and naturally occurring alternative protein sources while potentially reducing the amount of GHG emitted by traditional livestock farming. The success of novel foods, often developed through scientific research, relies on consumer perception and adoption. A desire to buy nutritious food produced sustainably drives consumer interest in novel foods (Caparros Megido et al., 2014). Yet, most Western consumers do not gravitate to novel foods unless they mimic traditional looks, tastes or sources, often reacting with disgust or dismissing novel foods as not a viable long-term option. The adoption of novel foods is hampered by entrenched attitudes, food-related concerns and socio-cultural norms.

Novel foods could help reduce the environmental impact of traditional farming by replacing some meat consumption, thereby reducing GHGs (Farchi et al., 2017; Njakou Djomo et al., 2020; Sans & Combris, 2015; Westhoek et al., 2014). Some studies find that a reduction by half in livestock farming could result in up to a 40% reduction in GHG emissions (Westhoek et al., 2014). A novel food is an innovative product that utilises new technologies or one that is or has been traditionally eaten outside a given jurisdiction, but not necessarily a newly developed food product (Tuorila & Hartmann, 2020). To date, no comprehensive examination of GHG emissions from the production of novel foods has been conducted. Given the scope of what is considered novel, this is unsurprising. In addition, food innovation exists on the frontier of the food supply chain and is often proprietary, making access to information about product development difficult. Therefore, it is difficult to compare emissions to traditional farming techniques. However, this does not alter the need to reduce the carbon footprint of traditional livestock farming or change the fact that reducing the impact of agriculture on climate change would require consumers to reduce traditional protein sources (Stehfest et al., 2009). The challenge for novel protein producers is to have consumers adopt the products in the face of traditional and long-held consumption patterns.

Human consumption of protein can be understood in two ways: health and culture. Meat is considered an important part of a healthy diet (Charlebois et al., 2020; Wyness, 2016). Meat provides essential nutrients such as protein and micronutrients such as iron, zinc and vitamin B12 (Godfray et al., 2018). However, in developed countries, meat tends to be overconsumed (Rust et al., 2020). While it is possible to obtain sufficient protein and nutrients without eating meat, it has an exalted place in Western culture. Present at almost all mealtimes and celebrations as a cultural norm, meat also serves as an expression of identity, legitimacy and masculinity (De Backer et al., 2020; De Groeve et al., 2019; Rosenfeld et al., 2019).

The year 2019 was a boon for plant-based protein products in the affluent North. Success stories such as Beyond Meat and the Impossible Burger brought plant-based protein alternatives out of the fringe-diet communities and into the mainstream (Heffernan, 2017). Indeed, plant-based proteins have been on the market for many years. Food items containing soy, tree nuts and legumes had attempted to replace traditional meat offerings with little success. While these meat substitutes create fewer emissions in their production process (Clune et al., 2017), they do not replicate meat in terms of taste, texture or smell. Consumers prefer beef burgers over plant-based alternatives (Slade, 2018; Tuorila & Hartmann, 2020). Given meat's cultural importance, plant-based alternatives face significant resistance from mainstream consumers.

In-vitro meat (IVM) exists on the edge of novel protein development. Grown in a laboratory environment using muscle stem cells, IVM presents a protein alternative that closely mimics traditional protein sources while using fewer resources and having a smaller carbon footprint (Bhat et al., 2019; Datar & Betti, 2010). However, for consumers, meat grown in a lab creates an ethical dilemma in addition to fear and disgust (Bryant & Barnett, 2019; Poirier & Russell, 2019; Zhang et al., 2020). Initial studies of IVM emissions suggest that cultured meat utilises fewer agricultural inputs and less total land than traditional farming (Mattick et al., 2015). However, Mattick et al. (2015) warn that despite this, "large-scale cultivation of in-vitro meat and the bioengineered products could represent a new phase of industrialisation with inherently complex and challenging trade-offs" (p. 11947).

There are protein alternatives consumed in cultures outside the Global North. An estimated 2 billion people regularly eat insects in some form (Nowak et al., 2016; Van Huis & Dunkel, 2017), while jellyfish food products are already popular in China and Southeast Asia, though this is based on limited species characterised by their stiffness and consistency (Leone et al., 2019). Due to climate change, the rise in ocean temperatures has seen exponential growth in the size and frequency of jellyfish blooms in waters globally (Torri et al., 2020). This has led to a focus on the potential growth of a global jellyfish fishing industry (Brotz & Pauly, 2017). Jellyfish may present a protein alternative that mitigates GHG by replacing or supplementing traditional protein sources and represents a financially viable product. Both insects and jellyfish are met with apprehension and disgust by consumers in most Western contexts. Indeed, Castro and Cham-

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ber (2019a) demonstrate wholesale rejection across 13 countries.

Consumer food choices have an impact on global climate change. The switch to sustainable and scientific agricultural products is paramount, but achieving consumer acceptance will be the largest hurdle. For example, a lack of motivation to eat more sustainably is a barrier to the regular consumption of plant-based meat alternatives (Hartmann & Siegrist, 2017). Valli et al. (2019) find that consumers are reluctant to reduce meat intake even in the face of negative health outcomes.

Canada presents an interesting case study for those concerned with strengthening sustainable agricultural practices. The average Canadian consumed 17.25 kg of beef and 16.84 kg of pork in 2019 (Government of Canada, 2020b) and 34.6 kg of chicken in 2018 (Government of Canada, 2020a). Comparatively, the United States consumed 26.3 kg of beef, 24 kg of pork and 50.1 kg of poultry (Organisation for Economic Co-operation and Development, [OECD] 2021). The United Kingdom consumed 11.4 kg of beef, 16 kg of pork and 30.1 kg of poultry during the same time frame (OECD, 2021). Although Canada is one of the largest global agricultural producers, research on the associated environmental footprint is in its infancy (Veeramani et al., 2017). Canada is not immune from the effects of climate change.

Consequently, many Canadians seek alternatives to traditional protein sources that will require scientific intervention to fulfil nutrition and sustainability goals but are less reliant on a globalised food chain. There is little research on how Canadian consumers perceive novel foods, such as insects, jellyfish or in-vitro meat products, as a potential food or food ingredient. Many studies consider consumer adoption of novel foods in terms of consumer neophobia, tolerance to disgust, health effects and policy; however, there are no studies in the literature specific to the Canadian context.

Therefore, to understand what product characteristics influence individual adoption levels of novel foods, we need to understand how socio-demographic variables intersect. In response to these challenges, this study aims to measure Canadian consumers' likelihood of adopting novel foods using two key personality traits, disgust and food neophobia. In addition, the study looks at key demographic information as well as novel food acceptance as predictors of favourable perceptions of sustainable agriculture techniques.

2. Methods

2.1 Research Methods

This study used a Qualtrics online survey platform to conduct the survey in French and English over seven days in June 2020. The sample was drawn from a panel hosted by Angus Reid, a Canadian market research firm. The survey sample was drawn from over 1.3 million self-selecting Canadian consumers to reach a cross-section of Canadians. The precision of Angus Reid Forum online polls is measured using a credibility interval. In this case, the poll is accurate to within± 3.2 percentage points, 19 times out of 20, had all Canadians been polled. The Research Ethics Board granted ethical approval at the researchers' home university. Respondents who may have found questions to be offensive or disturbing were encouraged to remove themselves from the survey. Data were collected using a quota system based on Canadian Census data from 2016 of age and gender; quotas on the sample are a representation of the population across six regions: British Columbia, the Prairies, Ontario, Quebec, the Atlantic Provinces, and the North. Incomplete responses were removed before data analysis leaving a total number of completes at 993.

The survey instrument was divided into eight sections. Sections 1 to 3 measured personality traits related to food neophobia and disgust of respondents. Sections 4 through 6 measured the likeliness to accept jellyfish, insects and in-vitro meat as food products. Section 7 probed respondents on attitudes towards sustainable agriculture practices. The last section focused on demographic considerations to better understand how gender, income, education, etc., affect the acceptance of novel foods.

In keeping with other studies that measure the likelihood of food adoption (Johns et al., 2011; Rioux, 2020; Torri et al., 2020), Pliner and Hobden's (1992) scale of measuring food neophobia was used to determine the likelihood of adoption of novel foods as a protein source. This study used a 5-point Likert scale—1 Strongly agree, 2 Agree, 3 Neither disagree nor agree, 4 Disagree, 5 Strongly disagree—for respondent comfort. Reverse statements were recalculated to give each respondent a score from 10 to 50, with higher scores indicating that respondents are more likely to try new foods and lower scores indicating a reluctance to try new foods.

Core disgust sensitivity was measured using an adapted version of Haidt et al.'s (1994) Disgust Scale. Due to the nature of some of the questions in the Disgust Scale, the response rate was lower and completion time in field was longer than anticipated. The scale was divided into two subscales with 5-point Likert scales; namely, 1 Strongly agree, 2 Agree, 3 Neither disagree nor agree, 4 Disagree, 5 Strongly disagree for subscale 1, and 1 Not at all disgusting, 2 Slightly disgusting, 3 Mildly disgusting, 4 Very disgusting, 5 Extremely disgusting for subscale 2. Some statements were reversed for internal consistency. Overall scores ranged from 14 to 70, with high scores indicating the participant experiences higher rates of disgust.

The survey explored three potential novel foods: jellyfish, insects and in-vitro meat. Three proteins were chosen among many suitable options as representatives of broad categories of alternative proteins. Insects as a general category was chosen because of recent investments in the Canadian market. Insect production plants have opened in three provinces, Alberta (Ward, 2018), Quebec (CBC News, 2018) and Ontario (Lancione, 2020), with considerable investment from the Canadian federal government (CBC, 2018; Lancione, 2020). Reports about edible insect protein have been a regular feature in national and provincial print and television media (Baxter, 2017; De Bono, 2020; Nguyen, 2020; Stephenson, 2018). Jellyfish, a natural resource, is an attractive option because producers would have low switching costs in an established fishing industry. Warming ocean temperatures have created an environment conducive to jellyfish blooms (Brotz & Pauly, 2017; Torri et al., 2020), making it a potentially profitable protein source. Although jellyfish are eaten as a protein source in international markets (Brotz et al., 2017; Brotz & Pauly, 2017), it is a novel protein option in Canada, where consumers rely on traditional protein sources. Finally, in-vitro meat was chosen as a broad category because it reflects the recent trend of technology-based imitation meat alternatives similar to the Beyond Beef Burger and the Impossible Burger (Splitter, 2019). Plant-based imitation meat is a conventional approach to protein alternatives that consumers utilise with specific dietary preferences or needs. Generally, these products are segregated from the traditional protein sources in the meat aisle in food markets. However, recent technological advancements in plant-based alternatives have gained popularity among consumers with no dietary preference and become more mainstream (Charlebois et al., 2020; O'Connor). Beyond Beef burger patties are now found in the meat aisle alongside traditional meat products (Bellon, 2019).

Each novel food was presented in 10 statements measuring acceptance with a 5-point Likert scale: 1 Strongly agree, 2 Agree, 3 Neither disagree nor agree, 4 Disagree, 5 Strongly disagree. Reverse statements were recalculated, and each participant was then given a score per novel food where a value of 1 to 3 was considered not at all accepting, 4 to 6 was considered moderately accepting and 7 to 10 was considered accepting. Each protein was presented without significant definitions on the state of the product (processed or whole food) to keep the survey simple for respondents and allow them to answer in accordance with their personal frame of reference. A series of statements about dietary changes was presented to better understand Canadians' attitudes towards sustainable agricultural practices. A 5-level Likert scale (1 Strongly agree, 2 Agree, 3 Neither disagree nor agree, 4 Disagree, 5 Strongly disagree) was used to measure both acceptance and willingness to change.

2.2 Data analysis

All statistical analysis was completed using IBM SPSS Statistics version 25. Cronbach's α was used to test the internal consistency and reliability of each part of the survey: food neophobia, disgust, willingness to eat each of the novel foods, and importance of sustainable agriculture. The dimensionality of the scores obtained in each survey section was examined using Exploratory Factor Analysis. Correlation between section questions and correlation between questions with each section's total score were measured by calculating Pearson's correlation coefficients. Principal Component Analysis was used to determine the relationships among variables further.

The corresponding score value was divided into three

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categories for each section of the survey based on their corresponding scale values. Scale values were obtained by dividing the range of the section into 10 segments and assigning a value from 1 to 10. Scale values of 1–3, 4–6 and 7–10 determined placement into one of three corresponding groups.

3. Results

3.1 Comparisons of Segmentations

Food neophobia (FN) was divided into unwilling, somewhat willing and willing to try new foods for groups of 5.2% (n = 52), 28.7% (n = 285) and 66.1% (n = 656) of the population, respectively. The unwilling group scored between 10–21 on the Likert scale (mean 17.6), whereas the somewhat willing group scored between 22–33 (mean 28.6) and the willing group scored between 34–50 (mean 40.9).

Disgust sensitivity (DS) was similarly divided into not easily disgusted, somewhat disgusted and easily disgusted for groups of 5.9% (n = 59), 67.5% (n = 670) and 26.6% (n = 264) of the population, respectively. The not easily disgusted group scored between 14–31 on the Likert scale (mean 28.7), whereas the somewhat disgusted group scored between 32–47 (mean 40.4) and the easily disgusted group scored between 48–70 (mean 52.3).

Of the novel foods, the jellyfish (JF) consumption scores were divided into unaccepting, somewhat accepting and accepting for groups of 30.2% (n = 300), 48.5% (n = 482) and 21.2% (n = 211) of the population, respectively. The unaccepting group scored between 10–21 on the Likert scale (mean 16.6), whereas the somewhat accepting group scored between 22–33 (mean 27.8) and the accepting group scored between 34–50 (mean 38.9).

Similarly, the insect (INSect) consumption scores were divided into unaccepting, somewhat accepting and accepting for groups of 32.6% (n = 324), 39.7% (n = 394) and 27.7% (n = 275) of the population, respectively. The unaccepting group scored between 10–21 on the Likert scale (mean 16.5), whereas the somewhat accepting group scored between 22–33 (mean 27.6) and the accepting group scored between 34–50 (mean 39.3).

The lab-grown meat (IVM) consumption scores were divided into unaccepting, somewhat accepting and accepting for groups of 14.2% (n = 141), 34.6% (n = 344) and 51.2% (n = 508) of the population, respectively. The unaccepting group scored between 10–21 on the Likert scale (mean 16.3), whereas the somewhat accepting group scored between 22–33 (mean 28.4) and the accepting group scored between 34–50 (mean 40.7).

Finally, the sustainable agriculture (SA) value scores were divided into unimportant, somewhat important and important for groups of 6.2% (n = 62), 35.1% (n = 349) and 58.6% (n = 582) of the population, respectively. The unimportant group scored between 7–15 on the Likert scale (mean 11.9), whereas the somewhat important group scored between 16–24 (mean 21.1) and the important group scored between 25–35 (mean 28.8).

3.2 Effects of demographics on acceptance scores (JF, INSect, IVM, SA)

Pearson correlation coefficients were computed to examine the relationships between the novel food acceptance scores (JF, INSect, IVM), personality traits (FN, DS), gender, age and sustainable agriculture value (SA). The significance criterion was set at alpha = 0.05. The novel food acceptance scores and the sustainable agriculture value score were further examined through hierarchical multiple linear regression (HMLR) analysis to identify which predictors had the greatest impact on the score values. The analysis focuses on the impact of the demographic predictors (age, gender) in step 1, in step 2 FN and DS are added and in step 3 the non-subject novel foods are added (i.e. INSect and IVM are added when examining JF; all three are added when examining SA). The analysis ends for SA after step 3; however, the novel foods examine an additional predictor when, in step 4, SA is added to check the impact of sustainable agriculture values. In this manner, the gradual addition permitted observation of whether and to what extent new variables contributed to the prediction of the score being analysed. The coefficients were examined for significant differences at a significance level of 5%.

3.3 Reliability

Satisfying internal consistency was found for both FN and DS scores, with Cronbach's alpha equal to 0.893 and 0.736, respectively. Results of the factor analysis showed that food neophobia possessed two dimensions, which were associated with an equal number of questions. Comparatively, disgust sensitivity was observed to possess four distinct dimensions, two of which were associated with five questions, and the other two dimensions were associated with two questions each.

Excellent internal consistency was found for the jellyfish acceptance score (Cronbach's alpha = 0.905), whose questions were all positively and significantly correlated. Loading scores from the exploratory factor analysis indicated that seven of the 10 questions described the first dimension, while three described a second dimension. Pearson correlation coefficients between questions ranged from 0.177 to 0.771, and the total correlation between questions and the JF score ranged from 0.512 for question 30 to 0.856 for question 31. PCs explained 66.95% of variability, with PC1 explaining 54.68% while PC2 explained 12.28%.

Similarly, excellent internal consistency was found for the insect acceptance score (Cronbach's alpha = 0.920), whose questions were all positively and significantly correlated. Loading scores from the exploratory factor analysis indicated that seven of the 10 questions described the first dimension, while three described a second dimension. Pearson correlation coefficients between questions ranged from 0.129 to 0.817, and the total correlation between questions and the INSect score ranged from 0.520 for question 40 to 0.876 for question 41. PCs explained 72.17% of variability, with PC1 explaining 58.66% while PC2 explained 13.51%.

Also, excellent internal consistency was found for the insect acceptance score (Cronbach's alpha = 0.920), whose questions were all positively and significantly correlated. Loading scores from the exploratory factor analysis indicated that seven of the 10 questions described the first dimension, while three described a second dimension. Pearson correlation coefficients between questions ranged from 0.129 to 0.817, and the total correlation between questions and the INSect score ranged from 0.520 for question 40 to 0.876 for question 41. PCs explained 72.17% of variability, with PC1 explaining 58.66% while PC2 explained 13.51%. The lab-grown meat acceptance score showed even greater internal consistency (Cronbach's alpha = 0.933) and displayed questions that were all positively and significantly correlated. Loading scores from the exploratory factor analysis indicated that five of the 10 questions described the first dimension and five described the second dimension. Pearson correlation coefficients between questions ranged from 0.241 to 0.855, and the total correlation between questions and the IVM score ranged from 0.600 for question 49 to 0.889 for question 44. PCs explained 73.17% of variability, with PC1 explaining 62.48% while PC2 explained 11.09%.

Finally, the value of sustainable agriculture score displayed very good internal consistency (Cronbach's alpha = 0.831), with questions that were all positively and significantly correlated. Loading scores from the exploratory factor analysis indicated that six of the seven questions described the first dimension, and question 56 described the second dimension. However, due to the low question count, no actions were taken to pursue one-dimensionality for the score. Pearson correlation coefficients between questions ranged from 0.072 to 0.652, and the total correlation between questions and the SA score ranged from 0.443 for question 56 to 0.826 for question 55. PCs explained 62.51% of variability, with PC1 explaining 51.68% while PC2 explained 10.83%.

3.4 Participant characteristics effects on FN & DS, JF, INSect, IVM

A gender effect was found for most variables (Table 1). Males scored higher than females for novel food acceptance (JF, INSect, IVM), while females scored higher for disgust sensitivity and sustainable agriculture value. The mean food neophobia values were approximately the same across genders.

Also, age affected all considered variables. Typically, the mean scores for each of the variables decreased as age increased. Notably, this implies that while disgust sensitivity decreased with age, food neophobia increased with age and consequently, the acceptance of novel foods decreased. Furthermore, sustainable agriculture practices are favoured by younger demo-

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graphics.

3.5 Relationships among FN, DS, JF, IN, IVM, SA, age, gender

Significant correlations between FN, DS, JF, INSect, IVM, SA, age and gender were found (Table 2) considering the totality of the subjects. FN was observed to be significantly negatively correlated with DS. Each of the novel foods (JF, INSect, IVM) displayed a significant, moderate, positive correlation with FN, and a significant, moderate, negative correlation with DS. Significant, moderate, positive correlations were observed between the novel food scores and SA; the strongest correlations among variables were observed between JF and INSect (rho = 0.574) and IVM and SA (rho = 0.525).

Age was observed to have a significant, weak, negative correlation with FN, while it did not have a significant correlation with DS; age was observed to have a significant, weak, negative correlation with each of the novel food acceptance scores and SA. Comparatively, gender did not have a significant correlation with FN, but displayed a significant, weak, positive correlation with DS and SA, and a significant, weak, negative correlation with the novel foods. These observations confirm trends observed with the mean values in Table 1. Region was not typically significantly correlated with the other variables; there were significant, weakly

Table 1. Effects of Age & Gender

Effects of Age & Gender															
Variable	Range	Mean	SD	Median	Gender				Age						
					Males	Females	F	p-value	18-25	26-39	40-54	55-73	74+	F	p-value
FN	10-50	36.13	8.13	37	36.31	35.98	0.176	0.675	37.69	37.77	35.60	34.67	35.03	7.039	<0.001
DS	14-70	42.88	7.49	43	40.57	44.91	37.882	<0.001	44.06	42.30	43.36	42.74	41.43	2.821	0.024
JF	10-50	26.75	8.72	27	27.95	25.68	7.994	0.005	29.18	28.67	26.20	24.84	24.68	9.756	<0.001
INSect	10-50	27.23	9.51	27	28.72	25.93	7.948	0.005	27.32	29.36	27.11	25.62	24.75	7.251	<0.001
IVM	10-50	33.02	9.66	34	34.42	31.79	4.502	0.034	36.83	34.71	31.58	31.75	30.80	10.66	<0.001
SA	7-35	25.01	5.62	26	24.18	25.73	14.316	<0.001	26.09	25.94	24.35	24.52	23.93	5.416	<0.001

FN – Food Neophobia; DS – Disgust; JF – Jellyfish; IVM – In Vitro Meat; SA – Sustainable Agriculture

Table 2. Pearson correlation coefficients within the attitude towards novel foods

Pearson correlation coefficients within the attitude towards novel foods (jellyfish consumption, JF; insect consumption, INSect; lab-grown meat consumption, IVM; sustainable agriculture, SA), personality traits (food neophobia, FN; sensitivity to disgust, DS) and demographics (gender, age, region). Pearson correlation coefficients in **bold** indicate a significant correlation (p ≤ 0.05).

Variables	FN	DS	JF	INSect	IVM	SA	Gender	Age	Region
FN	1								
DS	**-0.299**	1							
JF	**0.498**	**-0.407**	1						
INSect	**0.476**	**-0.493**	**0.574**	1					
IVM	**0.375**	**-0.312**	**0.427**	**0.445**	1				
SA	**0.289**	-0.010	**0.199**	**0.318**	**0.525**	1			
Gender	-0.020	**0.289**	**-0.130**	**-0.147**	**-0.136**	**0.138**	1		
Age	**-0.150**	-0.030	**-0.190**	**-0.127**	**-0.176**	**-0.119**	0.026	1	
Region	**-0.067**	-0.009	**-0.124**	-0.005	-0.009	**0.098**	0.031	0.041	1

FN – Food Neophobia; DS – Disgust; JF – Jellyfish; IVM – In Vitro Meat; SA – Sustainable Agriculture

Table 3a. Hierarchical multiple regression models explaining the attitude towards jellyfish as food

Hierarchical multiple regression models explaining the attitude towards jellyfish as food (JF; n=993)

JF	Variable	B	SE B	β
Step 1	Constant	34.510***	1.124	-
	Age	-1.531***	0.254	-0.187
	Gender	-2.185***	0.541	-0.125
Step 2	Constant	30.023***	2.163	-
	Age	-1.139***	0.215	-0.139
	Gender	-0.635	0.473	-0.036
	FN	0.419***	0.030	0.391
	DS	-0.331***	0.033	-0.284
Step 3	Constant	14.784***	2.347	-
	Age	-0.763***	0.202	-0.093
	Gender	-0.335	0.440	-0.019
	FN	0.259***	0.030	0.241
	DS	-0.155***	0.034	-0.133
	INSect	0.292***	0.029	0.319
	IVM	0.121***	0.025	0.134
Step 4	Constant	14.827***	2.340	-
	Age	-0.758***	0.201	-0.093
	Gender	-0.085	0.448	-0.005
	FN	0.266***	0.030	0.248
	DS	-0.135***	0.034	-0.116
	INSect	0.307***	0.029	0.334
	IVM	0.159***	0.028	0.176
	SA	-0.128**	0.047	-0.082

Note: R2 = 0.052 for Step 1 (p < 0.001), ΔR2 = 0.289 for Step 2, R2 = 0.341

for Step 2 (p < 0.001), ΔR2 = 0.094 for Step 3, R2 = 0.435 for Step 3

(p < 0.001), ΔR2 = 0.004 for Step 4, R2 = 0.439 for Step 4 (p<0.001).

*p < 0.05. ** p < 0.01. *** p < 0.001.

Table 3b. Hierarchical multiple regression models explaining the attitude towards insects as food

Hierarchical multiple regression models explaining the attitude towards insects as food (INSect; n=993)

INSect	Variable	B	SE B	β
Step 1	Constant	34.604***	1.235	-
	Age	-1.104***	0.279	-0.124
	Gender	-2.731***	0.594	-0.143
Step 2	Constant	36.452***	2.307	-
	Age	-0.769**	0.229	-0.086
	Gender	-0.504	0.505	-0.026
	FN	0.406***	0.031	0.347
	DS	-0.487***	0.035	-0.384
Step 3	Constant	20.621***	2.452	-
	Age	-0.198	0.216	-0.022
	Gender	-0.096	0.466	-0.005
	FN	0.214***	0.032	0.183
	DS	-0.336***	0.035	-0.264
	JF	0.329***	0.032	0.302
	IVM	0.158***	0.026	0.16
Step 4	Constant	19.459***	2.413	-
	Age	-0.188	0.212	-0.021
	Gender	-0.674	0.467	-0.035
	FN	0.184***	0.032	0.158
	DS	-0.368***	0.034	-0.29
	JF	0.334***	0.032	0.306
	IVM	0.062*	0.030	0.063
	SA	0.300***	0.048	0.178

Note: R2 = 0.037 for Step 1 (p < 0.001), ΔR2 = 0.332 for Step 2, R2 = 0.369

for Step 2 (p < 0.001), ΔR2 = 0.096 for Step 3, R2 = 0.465 for Step 3

(p < 0.001), ΔR2 = 0.021 for Step 4, R2 = 0.486 for Step 4 (p<0.001).

*p < 0.05. ** p < 0.01. *** p < 0.001.

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Table 3c. Hierarchical multiple regression models explaining the attitude towards lab-grown meat as food

Hierarchical multiple regression models explaining the attitude towards lab-grown meat as food (IVM; n = 993)

IVM	Variable	B	SE B	β
Step 1	Constant	41.433***	1.248	-
	Age	-1.568***	0.282	-0.173
	Gender	-2.539***	0.600	-0.131
Step 2	Constant	37.775***	2.627	-
	Age	-1.247***	0.261	-0.137
	Gender	-1.263*	0.575	-0.065
	FN	0.344***	0.036	0.290
	DS	-0.272***	0.040	-0.211
Step 3	Constant	23.979***	2.907	-
	Age	-0.859**	0.254	-0.095
	Gender	-1.031	0.551	-0.053
	FN	0.175***	0.039	0.147
	DS	-0.101*	0.043	-0.078
	JF	0.191***	0.040	0.172
	INSect	0.221***	0.037	0.218
Step 4	Constant	17.390***	2.572	-
	Age	-0.651**	0.223	-0.072
	Gender	-2.306***	0.488	-0.119
	FN	0.078	0.034	0.066
	DS	-0.196***	0.038	-0.152
	JF	0.193***	0.035	0.174
	INSect	0.069	0.034	0.068
	SA	0.783***	0.045	0.456

Note: R2 = 0.048 for Step 1 (p < 0.001), ΔR2 = 0.160 for Step 2, R2 = 0.208

for Step 2 (p < 0.001), ΔR2 = 0.074 for Step 3, R2 = 0.274 for Step 3

(p < 0.001), ΔR2 = 0.170 for Step 4, R2 = 0.444 for Step 4 (p<0.001).

*p < 0.05. ** p < 0.01. *** p < 0.001.

Table 3d. Hierarchical multiple regression models explaining the attitude towards sustainable agriculture

Hierarchical multiple regression models explaining the attitude towards sustainable agriculture (SA; n = 993)

SA	Variable	B	SE B	β
Step 1	Constant	24.440***	0.732	-
	Age	-0.649***	0.165	-0.123
	Gender	1.592***	0.352	0.141
Step 2	Constant	15.442***	1.619	-
	Age	-0.413*	0.161	-0.078
	Gender	1.531***	0.354	0.136
	FN	0.201***	0.022	0.291
	DS	0.027	0.025	0.035
Step 3	Constant	1.224	1.628	-
	Age	-0.008	0.138	-0.001
	Gender	1.937***	0.299	0.172
	FN	0.071**	0.021	0.102
	DS	0.151***	0.023	0.201
	JF	-0.059**	0.022	-0.092
	INSect	0.128***	0.02	0.217
	IVM	0.300***	0.017	0.515

Note: R2 = 0.034 for Step 1 (p < 0.001), ΔR2 = 0.078 for Step 2, R2 = 0.112

for Step 2 (p < 0.001), ΔR2 = 0.260 for Step 3, R2 = 0.372 for Step 3

(p < 0.001). *p < 0.05. ** p < 0.01. *** p < 0.001.

FN – Food Neophobia; DS – Disgust; JF – Jellyfish; IVM – In Vitro Meat; SA – Sustainable Agriculture

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negative correlations associated with FN and JF, and a significant, weakly positive correlation associated with SA.

For each of the novel foods and the sustainable agriculture variable, an HMLR was performed to assess the effect of gender, age, FN, DS, the other novel food scores, and SA as predictors. When assessing the predictors for JF, a four-step process was conducted (Table 3).

The inclusion of age and gender in the first step was significant, $R2= 0.052$, $F(2, 990) = 27.003$, $p<0.001$.

The addition of FN and DS in step 2 resulted in a large significant increase in
$R2$, $\Delta R2=0.289$, $\Delta F(2, 988) = 127.957$, $p<0.001$.

In the third step, the other novel food scores were added with a small significant increase in
$R2$, $\Delta R2=0.094$, $\Delta F(2, 986) = 126.386$, $p<0.001$.

The final step, which added SA, saw a very small significant increase in
$R2$, $\Delta R2=0.004$, $\Delta F(1, 985) = 110.122$, $p<0.001$.

INSect was the strongest positive predictor $\beta=0.334$, $t(985)=10.601$, $p<0.001$; FN was the next strongest predictor $\beta=0.248$, $t(985)=8.822$, $p<0.001$, followed by IVM with $\beta=0.176$, $t(985)=5.571$, $p<0.001$. DS was the most strongly negative predictor $\beta=-0.116$, $t(985)=-3.908$, $p<0.001$. These results suggest that lower DS and higher FN, INSect, and IVM resulted in higher JF. Age, gender, and SA were weak negative predictors.

Assessing the predictors for INSect also involved a four-step process (Table 3). The inclusion of age and gender in the first step was significant, $R2= 0.037$, $F(2, 990) = 18.895$, $p<0.001$. The addition of FN and DS in step 2 resulted in a large significant increase in R2, $\Delta R2=0.332$, $\Delta F(2, 988) = 144.530$, $p<0.001$. In the third step the other novel food scores were added with a small significant increase in R2, $\Delta R2=0.096$, $\Delta F(2, 986) = 142.927$, $p<0.001$. The final step, which added SA, saw another small significant increase in R2, $\Delta R2=0.021$, $\Delta F(1, 985) = 132.922$, $p<0.001$. JF was the strongest positive predictor $\beta=0.306$, $t(985)=10.601$, $p<0.001$; SA was the next strongest predictor $\beta=0.178$, $t(985)=6.281$, $p<0.001$, followed by FN with $\beta=0.158$, $t(985)=5.728$, $p<0.001$. DS was the most strongly negative predictor with $\beta=-0.290$, $t(985)=-10.726$, $p<0.001$. These results suggest that lower DS and higher FN, JF, and SA resulted in higher INSect scores. Age and gender were not significant predictors; IVM was a weakly positive predictor with a lower significance ($p<0.05$).

Another four-step HMLR process assessed the predictors for IVM (Table 3c).

The inclusion of age and gender in the first step was significant, $R2= 0.048$, $F(2, 990) = 25.079$, $p<0.001$.

The addition of FN and DS in step 2 resulted in a moderate significant increase in
$R2$, $\Delta R2=0.160$, $\Delta F(2, 988) = 64.734$, $p<0.001$.

In the third step the other novel food scores were added with a small significant increase in
$R2$, $\Delta R2=0.074$, $\Delta F(2, 986) = 62.017$, $p<0.001$.

The final step, which added SA, saw another moderate significant increase in
$R2$, $\Delta R2=0.170$, $\Delta F(1, 985) = 112.582$, $p<0.001$.

SA was the strongest positive predictor $\beta=0.456$, $t(985)=17.386$, $p<0.001$; JF was the next strongest predictor $\beta=0.174$, $t(985)=5.571$, $p<0.001$. DS was the most strongly negative predictor with $\beta=-0.152$, $t(985)=-5.186$, $p<0.001$, followed by gender with $\beta=-0.119$, $t(985)=-4.725$, $p<0.001$. These results suggest that lower DS and higher SA and JF resulted in higher IVM scores; the results also indicate that males are more accepting of IVM as a food source. FN and INSect were not significant predictors; age was a weakly negative predictor with a lower significance ($p<0.01$).

Finally, a three-step HMLR process assessed the predictors for SA (Table 3d). The inclusion of age and gender in the first step was significant, $R2= 0.034$, $F(2, 990) = 17.510$, $p<0.001$. The addition of FN and DS in step 2 resulted in a small significant increase in R2, $\Delta R2=0.078$, $\Delta F(2, 988) = 31.142$, $p<0.001$. In the final step, the novel food scores were added with a large significant increase in R2, $\Delta R2=0.260$, $\Delta F(3, 985) = 83.475$, $p<0.001$. IVM was the strongest positive predictor, $\beta=0.515$, $t(985)=17.386$, $p<0.001$; INSect was the next strongest predictor, $\beta=0.217$, $t(985)=6.281$, $p<0.001$, followed by DS with $\beta=0.201$, $t(985)=6.516$,

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p<0.001, and gender with β=0.172, t(985)=6.478, p<0.001. These results suggest that higher IVM, INSect and DS scores resulted in higher SA scores; the results also indicate that females are more likely to value sustainable agriculture. FN was a less significant positive predictor (p<0.01), whereas JF was a less significant negative predictor (p<0.01); age is not a significant predictor for SA scores.

4. Discussion

Producing beef for mass protein consumption is arguably the most damaging of food systems in terms of GHG and a critical element in facilitating the progress of anthropogenic climate change. Therefore, diversifying protein intake to include offerings with less GHG emissions provides a unique challenge to global food systems where beef has exalted status. Nevertheless, if food systems scientists are serious about reducing GHG from protein intake, consumers' willingness to adopt alternative proteins must be considered. Simply expanding the availability of different proteins to consumers does not necessarily mean they switch to lower emissions choices, as evidenced by this survey.

This analysis compares three types of alternative proteins—cultured meat, jellyfish and insects. Of the three, jellyfish had the lowest overall adoption score. This is unsurprising given that jellyfish is not traditionally consumed in Canadian culture and is viewed as a pest by many Canadians because of their effect on tourism and traditional fisheries (Brotz et al., 2017). Perhaps jellyfish would not be viable as a main course for dinner, but processed jellyfish could be a source of protein as an additive to other foods, including soups, salads and dessert dishes such as ice cream (Simpson, 2009).

The viability of both insects and jellyfish as processed ingredients for other foods has potential. Start-up food tech companies are exploring both for their richness in protein (Mintah et al., 2020) and omega and collagen properties (Khong et al., 2016). Yet, each has specific hurdles that must be overcome. First, insects are generally thought of as 'dirty' (Castro & Chambers, 2019b). Given the breadth of insect types, consumers will not discern edible insects from household pests.

While processors can reduce insects to powder, the data from the disgust scale in this study suggests that years of insect avoidance requires more than novelty to win over consumers. Jellyfish, on the other hand, is elusive for most consumers as many have never encountered them in their natural environment. However, the texture of jellyfish is difficult to overcome for most people. Once processed, jellyfish could become a nutraceutical with antioxidant benefits (Leone et al., 2019). Further research on the likelihood of adoption of these proteins as processed additives is warranted.

The results show that age is a significant indicator of adopting alternative proteins, with older demographics less likely to adopt new sources. However, older demographics are more likely to adopt cultured meat than other alternative protein sources. This is in keeping with research coming out of the United States (Van Loo et al., 2020). This could be because of the imitation of traditional meat sources in which texture and flavour are familiar. Scientists have not been able to replicate the best cuts of beef with cultured meat (Purdy, 2020; Stephens et al., 2018). Of the three alternatives presented, cultured meat is still experimental and expensive to produce; moreover, regulatory frameworks prohibit its sale in the Canadian market (Hopkins, 2015; Purdy, 2020). However, investment in insects as a source of protein has been met with favourable regulatory environments and media attention (CBC, 2018; Lancione, 2020; Nguyen, 2020; Stephenson, 2018). Still, the environmental consequences of switching to cultured meat as a replacement for traditional beef remain unclear.

Gender was a significant factor in the perception of sustainable agriculture. Female respondents were more in favour of the promotion of sustainable agriculture techniques but less likely to adopt alternative proteins to support sustainable agriculture. This could be because women are more likely to adopt plant-based diets (Charlebois et al., 2020; Rosenfeld, 2020) or flexitarian approaches to dieting (Rosenfeld et al., 2019). Unsurprisingly, those respondents who were likely to adopt any of the three alternative proteins in the survey were more favourably disposed towards sustainable agriculture overall. This suggests a link between the two and a problem for those looking to change agriculture techniques. Success with sustainable agriculture depends, in part, on consumer buy-in. The results of this study serve as a warning to investors, both private and public, that consumers have a significant role in the success of new foods. In the case of insects, despite insect farming and edible insect initiatives gaining popularity in the Canadian market for investors, media and the federal government, the fact remains that the consumers have not warmed to the idea of consuming insects as a regular protein alternative. This implies that insects may be better used as an input to traditional farming than as a food product on the shelves of supermarkets, though the environmental benefits of doing so remain uncertain. Further, consumers were also reticent about consuming jellyfish as an alternative protein. This suggests that even though natural resources could be exploited cost-effectively with potential benefits to ocean systems, this would not overcome consumers' reluctance to switch from traditional to alternative seafood. However, it should be mentioned that lobster, once considered a lower-income food worthy only of servants and prisoners, overcame social taboos to become a highly sought-after seafood (Tye et al., 2011). Perhaps jellyfish could experience the same cultural relevance over time.

Interestingly, this research implies that a pathway to sustainable agriculture in Canada lies with science and technology, but it might be the farthest from becoming a reality due to an unfriendly regulatory environment and consumer preference. This is unsurprising as the food industry has a history of pivoting to imitation to satisfy alternative dietary choices rather than switching. While the regulatory bodies dither on allowing cultured meat into the Canadian market, technology investments support international start-ups working on viable cultured meat options (Stephens et al., 2018), leaving Canadian alternatives to fall behind in the science and potential market share (Purdy, 2020).

There are limitations with this research. First, this is self-reported survey data. It could be that respondents were aspirational in the responses rather than truthful (Subar et al., 2015). In addition, it is impossible to declare whether food neophobia changes over time using these data. The data suggest that younger respondents are less likely to exhibit food neophobia, but there is no indication that this will remain steady as those respondents age. The study analysed only three alternative sources of protein among many. These were chosen based on popular Canadian media reports. Future research should include a wider variety of alternative protein sources. Finally, alternative protein sources were presented without the suggestion of how they may be consumed. This was done so as not to bias potential responses.

5. Conclusions

This study reveals initial insights into the adoption of alternative proteins in the Canadian context. Canadian protein consumption has far-reaching global environmental consequences, impacting middle- and lower-income countries globally. Canadian consumers must seriously consider making changes to traditional agricultural techniques that release high amounts of GHG into the atmosphere. Cultured or in-vitro meat might be a viable pathway for food systems to reduce harmful impacts of traditional agriculture if scientists can successfully imitate popular beef cuts and, most importantly, ensure that cultured meat does not create a different but similarly harmful set of environmental externalities. Nevertheless, cultured meat remains in regulatory limbo as policymakers are reluctant to allow it into the protein marketplace.

Adopting sustainable food systems will necessitate a move away from traditional protein sources. However, the challenge remains that consumers, producers and policymakers in Canada are reluctant to do so, even in the face of anthropogenic climate change. Whether science can offer exact replicas of traditional protein sources or consumers adopt protein sources popular in other cultures, change is slow to take place. It is encouraging that younger generations see the need for change in order to reduce the carbon footprint of the protein food supply. However, without producers and policymakers fully understanding consumers' perceptions of alternative proteins, serious reduction in environmental consequences from protein production will be slow or miss the mark completely.

Conflict of interest

The authors declare no conflict of interest. The funder had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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