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# Perceptions and acceptance of yeast-derived dairy in British Columbia, Canada

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Yeast derived-dairy (YDD) produced using cellular agriculture technologies is already available for purchase in the United States, though there has been little study of public understanding of these products. Our pilot study explored consumer perception and acceptance of YDD and yeast-derived agriculture (YDA). The study employed a questionnaire consisting of Likert scale, multiple-choice and open-ended questions, which was disseminated to vegans and the food-interested public in the province of British Columbia, Canada. Quantitative data was analyzed using SPSS 27.0, and qualitative data was collected and analyzed (in English) using thematic analysis. A binary logistic regression model indicated that among our participants, being vegan or 35 years of age or older negatively predicted having positive feelings towards YDA [chi-square (10)=29.086,  $p=0.001$ ]. Vegans were less likely to try or purchase YDD than non-vegans. Consumers in our study shared concerns regarding the health and safety of YDD with many viewing it as non-vegan and a highly processed product. Although vegans receive a disproportionate amount of media attention with regards to cellular agriculture, our pilot study suggests this group may be unlikely to accept or consume YDA or YDD. Rather, our preliminary work indicates non-vegans and individuals under the age of 35 may be a more receptive market. Across groups, confusion about YDA processes may be a barrier to adoption.

## KEYWORDS

yeast-derived dairy, cellular agriculture, vegan, consumer perception, British Columbia

## 1. Introduction

Consumption of dairy products across the globe is changing. Plant-based milk sales increased 61% between 2012 and 2017 in the United States (Mintel, 2018), while almost a quarter (23%) of individuals in the UK consumed plant-based milks in 2019 (Mintel, 2019). In Canada, consumption of milk and dairy has steadily decreased over the past decade (Statistics Canada, 2017). The removal of the dairy section from the Canada Food Guide further illuminates these shifts, as dairy products have been a long-standing staple of Canadian diets (Health Canada, 2019). Concerns surrounding ethics, environmental impact, health, and safety have all helped fuel the shift away from conventional dairy toward plant-based alternatives. New varieties of plant-based milk and dairy alternatives from various nuts, oat, hemp, pea and coconut are indicative of the rapid growth and expansion potential of this market.

New technologies also hold the potential to further change the landscape of dairy consumption in Canada and across the globe. Cellular agriculture refers to a set of technologies used in the production of agricultural products like meat, dairy, eggs, and others using cell cultures rather than relying on animals. It has garnered media and academic attention,

particularly since 2012, when the first lab grown beef patty was produced by Mark Post's research group at Maastricht University (Post et al., 2020 discusses this in detail). Although lab-grown meat is still likely years away from widespread commercial availability, another application of cellular agriculture, yeast derived-dairy (YDD), is already producing biologically equivalent dairy and milk products for market in the United States. Perfect Day, a San Francisco-based company, has successfully created and marketed their fermentation-derived dairy proteins, now available for purchase in ice-cream made by Smitten. Perfect Day has also expanded to create their own ice cream company, Brave Robot.

Although consumers are already able to enjoy “milk without the moo” (Pandya, 2014), little is known about consumer perceptions and acceptance of this food, particularly among the food-interested public and vegans, of which the latter are often regarded as a key demographic for this novel food (Mendly-Zambo et al., 2021). A 2018 market research study in Great Britain led by a private sector firm gave some insights into consumer interest in YDD (Perkins, 2018), and a study based on focus group conducted in 2021 with 42 participants across Germany, the United States, and Singapore was published as this article was in the late stages of preparation (Broad et al., 2022). Additional research is needed, particularly in regions like Canada, not covered by these studies. The aim of our study was to contribute to addressing this gap in knowledge by collecting information regarding consumer attitudes and perceptions of cellular agriculture technologies, particularly YDD, in the Canadian province of British Columbia (BC). As this was a pilot study, our aim was both to gain preliminary data for analysis, and to use this to inform our team's future research on YDD.

## 1.1. Overview of cellular agriculture and cellular dairy

Cellular agriculture refers to a set of technologies used in the production of traditionally animal-derived meat, dairy, fish, and eggs, without relying on sentient animals. Unlike the ubiquitous and growing dairy alternatives, including nut, soy, and oat milks, which aim to be viscerally equivalent to dairy, YDD, and other foods produced using cellular agriculture technologies are biologically equivalent and therefore have the same eating and cooking experience as foods produced from animals (Stephens et al., 2018).

Cellular agriculture has two main avenues of production, cellular and acellular. YDD is made by a process of acellular production which uses recombinant microorganisms to produce milk proteins (casein and whey) through a process of fermentation (Tuomisto et al., 2017). Isolated and purified milk proteins are combined with specific ratios of plant-sourced fats, minerals, sugar, and clean water to create biologically equivalent milk (Pandya, 2014) that is described as “animal-free dairy” by companies currently producing it, such as Perfect Day (2020b). As yeast is used in this process, this novel dairy is referred to as yeast-derived dairy, or fermentation-derived dairy, although nomenclature is not yet consistent. Although a novel application, the techniques used in acellular production, which may be broadly framed as yeast-derived agriculture (YDA), are not new, and have already been used for decades in the processes of making insulin and rennet, and more recently in the production of leghemoglobin, a key ingredient responsible for the flavor and aroma of cooked meat in the Impossible Food's Impossible Burger (Shapiro, 2018).

## 1.2. Consumer acceptance and perceptions of cellular agriculture

Numerous consumer perception and acceptance studies on cellular agriculture have been conducted worldwide (for review see Bryant and Barnett, 2018, 2020); to date, however, these studies have focused primarily on cultured meat production, save for Perkins (2018) and Broad et al. (2022) discussed in Section 1.1. Although yeast-derived dairy and cultured meat have different production processes, they are both foods which are biologically equivalent to animal products and stem from cellular agriculture technologies. Accordingly, both categories of foods raise similar questions about consumer perceptions and acceptance, and we can learn from consumer studies which focused on meat products.

There is a noted lack of uniformity in study design and methods employed in consumer perception studies to date; approaches have included focus groups, surveys, and media analysis (Bryant and Barnett, 2018), as well as examinations of how cellular agriculture technologies are described and the nomenclature used (Bekker et al., 2017; Siegrist et al., 2018; Bryant and Barnett, 2019). As reviewed by Bryant and Barnett (2020), despite this variation in study design, a few key groups stand out as more accepting of cultured meat, including younger men (Wilks and Phillips, 2017; Slade, 2018), individuals with higher levels of education (Gómez-Luciano and de Aguiar, 2019; Mancini and Antonioli, 2019; Weinrich et al., 2020), individuals who are of left leaning political orientation (Wilks and Phillips, 2017; Bryant et al., 2019), and urban city dwellers (Tucker, 2014; Shaw and Iomaire, 2019). Furthermore, familiarity with cultured meat has also been a predictor of acceptance (Bryant et al., 2019). The relationship between income and acceptance of cultured meat, however, is less clear, with some studies finding that those in lower income brackets were more willing to try cultured meat (Wilks and Phillips, 2017), while other studies found the opposite (Bryant et al., 2019; Gómez-Luciano and de Aguiar, 2019). Lastly, although they receive a disproportionate amount of media attention on the subject of cellular agriculture (Hopkins, 2015), prior studies have indicated vegetarians and vegans are less likely to try, eat, or purchase cultured meat as compared to omnivores (Wilks and Phillips, 2017; Bryant et al., 2019; Valente et al., 2019; Arora et al., 2020).

## 2. Methods

### 2.1. Study overview

The purpose of this pilot study was to gauge sentiments of food-interested consumers, including vegans, toward YDA and YDD in the province of British Columbia, Canada. Data collection for this research was collected via survey, hosted on web platform SurveyMonkey. The survey consisted of a mix of Likert scale questions, multiple choice as well as open ended questions, providing a rich mixture of quantitative and qualitative data. The survey also included information explaining what cellular agriculture is and how it is produced, through an “explainer” document developed by the study team (see [Supplementary information](#)). The study team asked several individuals to review the document for clarity and ease of understanding before the survey began.

## 2.2. Participants and recruitment

Recruitment of both general food-interested consumers and vegans and others who avoid eating dairy took place through multiple channels, including listservs, social media outreach (e.g., Twitter and Facebook), and direct outreach, all focused on British Columbia, Canada. We also recruited participants using the BC Food Systems Network and Canadian Association for Food Studies listservs. Additionally, we recruited undergraduate students for the study via email to class listservs. Responses to the study were collected between May and July of 2019. We acknowledge the sample for this pilot study was not representative of the general population (for example, in education level); however, it can provide some preliminary insights which are useful both for building an understanding of how consumers perceive YDD, and to help develop strategies for future, more extensive work.

## 2.3. Quantitative analysis

Data analysis of the consumer survey was conducted in software SPSS 27 (IBM). In this study, 5-point Likert scales were used for the majority of questions. To simplify the data analysis, variables used in statistical analysis were transformed from a 5-point scale into a 3-point Likert scale using SPSS. Specifically, “very likely” and “likely” became “likely,” “neither likely nor unlikely” became “neutral,” and “very unlikely” and “unlikely” became “unlikely.” The same process occurred for “agree” and “disagree” Likert scale questions.

Attitudes towards and perceptions of yeast-derived agriculture were examined through eight different statements pertaining to yeast-derived agriculture, and a series of Mann–Whitney tests were conducted to determine if vegans and non-vegans’ likelihood of

agreeing with those statements were significantly different. In addition, a series of Pearson Chi-square test statistics were conducted to examine if there was a difference between vegans and non-vegans’ likelihood to try, purchase, incorporate and replace milk or cream and ice cream with yeast-derived dairy alternatives.

A binary logistic regression model was conducted to explore what factors predicted individuals having positive feelings towards yeast-derived agriculture. The dependent variable for this regression was binary, either “agree” (containing strongly agree and agree) or “disagree” (containing neutral, disagree and strongly disagree) to the statement “Overall, my feelings towards yeast-derived agriculture are positive.” The binary variable was computed from an ordinal variable for simplicity using SPSS, a process has been shown to not significantly impact statistical outcome (Manor et al., 2000).

To achieve parsimony in our analysis, levels of predictor variables were also collapsed using SPSS (Lund and Raimi, 2012). For diet, survey participants were classified as being either vegan, or not vegan (which was an umbrella variable for every other dietary option, including “other,” on the survey). Age was also made into a binary variable for those who were 34 years of age and under, and those who were 35 years of age and over. Income was categorized as those who had a household income less than \$49,999 per year, those between \$50,000 and \$99,999 per year, and those who earned \$100,000 or over per year. Knowledge of the food system was categorized as those “having excellent” or “very good” knowledge of the food system, those who had “good” or “fair knowledge” and those who had “poor” or “no knowledge” of the food system. Finally, education categories taken from Statistics Canada census data were reduced from six to four categories with “No certificate diploma or degree” grouped together with “Secondary school diploma” and “Some undergraduate coursework” grouped together with “Undergraduate degree (e.g., B.A., B.Sc.)” Demographics, including frequency and percent, are presented in Table 1 for these variables.

TABLE 1 Respondent demographics.

Demographics		%	<i>n</i>
Age	34 years or younger	38.3	44
	35 years or older	61.7	71
Gender	Male	19.10	22
	Female	78.30	90
	Prefer not to say	1.7	2
Education	No certificate diploma or degree and or Secondary school diploma	7.8	9
	Apprenticeship or trades certificate or diploma	8.7	10
	Some undergraduate coursework and or Undergraduate degree (e.g., B.A., B.Sc.)	54.8	63
	Graduate degree (e.g., M.S., M.A., M.B.A., M.D., Ph.D.)	27.0	31
Annual household income (CAD)	Less than \$49,999	29.6	34
	Between \$50,000 - \$99,999	35.7	41
	\$100,000 and above	33.0	38
Diet	Vegan	38.3	44
	Non-vegan	61.7	71
Knowledge of the food system	Excellent and Very good	51.3	59
	Good and Fair	40.9	47
	Poor and Unfamiliar with the term ‘food system’	6.1	7

## 2.4. Qualitative analysis

Open-ended responses from the consumer survey were collected in two separate questions in the survey, including the question “I would be more likely to consume yeast-derived dairy if it...” and at the end of the survey when respondents were asked to express any comments, questions or concerns regarding cellular agriculture and or yeast-derived dairy that they may have. Responses from these written questions were collected and analyzed (in English) using thematic analysis as described by Braun and Clarke (2006). To do this, responses were collected in an Excel sheet; words were generated from the content of the responses. Next, responses were sorted based on these codes, and themes were identified across the codes. Two researchers reviewed the sorting and made adjustments as necessary.

## 3. Results and discussion

A total of 127 people responded to the survey. After removing participants who either did not meet the inclusion criteria, or those who did not answer a sufficient number of questions, 115 survey participants remained in this study. Of these 115 respondents, 78.3% were women, 61.7% were 35 years of age or older, and 38.3% followed a vegan diet (Table 1).

Compared with the general Canadian population, our sample population was well-educated and wealthy. Nearly a third of respondents indicated having a graduate degree (27%), well above the population rate for Canada (6.1%; Statistics Canada, 2017). A total of 67% of all respondents earned a household income of \$50,000 or over, much higher than the rate within the Canadian population of 33%. Lastly, 51.3% of respondents reported having excellent or very good knowledge of the food system, 40.9% reporting having good or fair knowledge, and 6.1% had either poor knowledge or no knowledge of the food system.

### 3.1. Familiarity

Approximately 56% of participants responded that they had heard of cellular agriculture, and 34.8% of respondents said that they had heard of it and understood what it was. The remaining 44% of participants had not heard of cellular agriculture prior to this study. Our questions were phrased similarly to questions outlined in Verbeke et al.'s, 2015 study on consumer acceptance of *in vitro* meat for comparability. In their study 13% of respondents had heard of *in vitro* meat and knew what it was, where 36.0% had heard of it but did not know what it meant, and 51% had never heard of *in vitro* meat (Verbeke et al., 2015). While numbers from our survey and theirs are quite different, their survey was conducted several years before ours, when there was substantially less media discourse around cellular agriculture.

Of those respondents to our survey who indicated familiarity with YDA, a majority were aware that meat was being produced using cellular-agriculture technologies, followed by dairy, leather, wood and “other.” They were given the option to specify what “other” was and respondents listed organs, insulin, rennet, and seafood (salmon).

### 3.2. Openness to yeast derived dairy

In the survey questionnaire, participants were asked how likely they would be to try, purchase, incorporate and replace milk or cream and ice cream with yeast-derived dairy alternatives (Table 2). A total of 43.5 and 38.3% of participants indicated they would be either likely or very likely to try milk/cream or ice cream. Overall, survey respondents indicated more willingness to try and or to purchase milk/cream or ice cream, compared with incorporating it regularly into their diet, or replacing their current consumption altogether. This trend is consistent with consumer *in vitro* meat studies (Wilks and Phillips, 2017; Mancini and Antonioli, 2019; Weinrich et al., 2020) suggesting that overall, consumers are currently less likely to regularly consume or entirely replace their consumption of animal derived-foods with ones derived using cellular agriculture technologies.

Furthermore, compared with non-vegan respondents, vegan respondents in this pilot study were less likely to try, purchase, incorporate and replace milk/cream or ice cream with YDA products altogether. Pearson Chi-square test statistic (Table A1) revealed that the difference between vegans and non-vegans' willingness to replace milk or cream ( $\chi^2=6.973, p=0.008$ ) and ice cream ( $\chi^2=8.755, p=0.003$ ) was significantly different, as was willingness to try ice cream ( $\chi^2=3.8777, p=0.049$ ) with vegans again being less likely to do so in all cases. Other consumer perception studies have also shown that vegetarians and vegans find *in vitro* meat less appealing compared to meat-eaters (Wilks and Phillips, 2017; Valente et al., 2019; Arora et al., 2020). Men and individuals under the age of 35 in this pilot study also indicated a higher willingness to try YDA at 54.5 and 52.3% respectively, compared with women (40.0%) and those 35 years of age or older (38.0%).

### 3.3. Perceptions of yeast derived agriculture

To examine attitudes toward and perceptions of yeast-derived agriculture, survey respondents were asked to indicate whether they agreed, disagreed, or were neutral with regards to eight different statements pertaining to yeast-derived agriculture (Table 3). Majorities of respondents perceived YDA as contributing to factors typically associated with sustainability; 65.2% agreed

TABLE 2 Likelihood to try, incorporate, and replace milk or cream and ice cream with yeast-derived dairy alternatives.

Food type		All % (n)	Vegan % (n)	Non-vegan % (n)
Milk or Cream	Try	43.5 (50)	34.1 (15)	49.3 (35)
	Purchase	31.3 (36)	25.0 (11)	35.2 (25)
	Incorporate	25.2 (29)	8.2 (8)	29.6 (21)
	Replace	15.7 (18)	4.5 (2)	22.5 (16)
Ice cream	Try	38.3 (44)	27.3 (12)	45.1 (32)
	Purchase	27.8 (32)	20.5 (9)	32.4 (23)
	Incorporate	20.0 (23)	11.4 (5)	25.4 (18)
	Replace	17.4 (20)	4.5 (2)	25.4 (18)

\*Data shows respondents who were either 'very likely' or 'likely' to try, incorporate, replace and purchase yeast derived milk or cream, and ice cream.

TABLE 3 Perceptions and attitudes towards yeast-derived agriculture.

		Agree & strongly agree % (n)	Neutral % (n)	Disagree & strongly disagree % (n)
Yeast-derived agriculture is a technology that will have positive impacts on the environment	All	65.2 (75)	28.7 (37)	6.1 (7)
	Vegans	63.6 (28)	34.1 (15)	2.3 (1)
	Non-vegans	66.2 (47)	25.4 (18)	8.5 (6)
Yeast-derived agriculture is a technology that will have positive impacts on the well-being of animals	All	68.7 (79)	26.1 (30)	5.2 (6)
	Vegans	72.7 (32)	22.7 (10)	4.5 (2)
	Non-vegans	66.2 (47)	28.2 (20)	5.6 (4)
Yeast-derived agriculture is an environmentally sustainable alternative to traditional dairy	All	64.3 (74)	30.4 (35)	5.2 (6)
	Vegans	66.9 (29)	34.1 (15)	0 (0)
	Non-vegans	63.4 (45)	28.2 (20)	8.5 (6)
Yeast-derived agriculture is a technology that will have positive impacts on the health and well-being of humans	All	26.1 (30)	50.4 (58)	23.5 (27)
	Vegans	15.9 (7)	54.5 (24)	29.5 (13)
	Non-vegans	32.4 (23)	47.9 (34)	19.7 (14)
Products made using yeast-derived agriculture technologies are: 'animal free'	All	42.6 (49)	34.8 (40)	22.6 (26)
	Vegans	29.5 (13)	38.6 (17)	31.8 (14)
	Non-vegans	50.7 (36)	32.4 (23)	16.9 (12)
Products made using yeast-derived agriculture technologies are: vegan	All	27.0 (31)	42.6 (49)	30.4 (35)
	Vegans	20.5 (9)	40.9 (18)	38.6 (17)
	Non-vegans	31.0 (22)	43.7 (31)	25.4 (18)
Products made using yeast-derived agriculture technologies are: vegetarian	All	50.4 (58)	33.0 (38)	16.5 (19)
	Vegans	50.0 (22)	29.5 (13)	20.5 (9)
	Non-vegans	50.7 (36)	35.2 (25)	14.1 (10)
Overall, my feelings towards yeast-derived agriculture are positive	All	46.1 (53)	35.7 (41)	18.3 (21)
	Vegans	38.6 (17)	40.9 (18)	20.5 (9)
	Non-vegans	50.7 (36)	32.4 (23)	16.9 (12)

with the statement “Yeast-derived agriculture is a technology that will have positive impacts on the environment”; 68.7% agreed with a similar statement about the wellbeing of animals; and 64.3% agreed with the statement that it was a sustainable alternative to traditional dairy. Only 26.1% of respondents in this pilot study, however, agreed that this technology would have a positive impact on the health and well-being of humans. A majority of respondents (50.4%) indicated they were neutral on this statement. A low value was observed for the statement that YDA was “vegan,” with only 27% agreeing. In contrast, 50.4% percent of participants agreed with the statement that YDA was vegetarian and 42.6% considered it “animal-free.” Further research examining the difference in perceptions between what makes a product vegetarian, vegan and animal-free with regards to YDA is needed, particularly as Perfect Day, the company currently making YDD products, describes their products as both “animal-free” and “vegan.” Lastly, 46% of respondents indicated having positive feelings towards YDA. Predictors of having positive feelings towards YDA are explored further in binary regression analysis discussed below.

Broken down by diet, both vegans and non-vegans agreed similarly that YDA would have positive impacts on the environment and on the well-being of animals. They both agreed that YDA is an environmentally sustainable alternative to traditional dairy, with

vegans agreeing at a slightly higher rate, although this difference was not statistically significant. Vegans in this pilot study were less in agreement (16%) compared to non-vegans (32%) that YDA would have a positive impact on the health and well-being of humans. More vegans disagreed with the statement that products made using YDA technologies were vegan (38.6% compared with 25.4% for non-vegans), as well as with the statement that YDA technologies were “animal-free” (31.8% compared with 16.9% for non-vegans). For the latter, a Mann–Whitney test showed that this difference in responses between vegans and non-vegans was statistically significant ( $U = 1172.50$ ,  $p = 0.016$ ; Table A2). Lastly, fewer vegans in this pilot study reported having positive feelings towards YDA, and vegans overall did not see YDA as fitting within their ethical code regarding food production and consumption, but these differences were not statistically significant.

### 3.4. Positive feelings

A binary logistic regression model was conducted to test what factors predicted respondents in our pilot study agreeing (including strongly agree and agree) with the statement “Overall, my feelings towards yeast-derived agriculture are positive”

TABLE 4 Binary logistic regression for positive feelings towards yeast-derived agriculture.

Binary logistic regression	B	S.E.	Wald	df	p value	Exp (B)	95% CI Lower	Upper
Independent variable								
35 years of age or older	-1.893	0.611	9.602	1	0.002*	0.151	0.045	0.499
Vegan	-1.068	0.515	4.298	1	0.038*	0.344	0.125	0.943
No certificate diploma or degree + Secondary school diploma			3.529	3	0.317			
Apprenticeship or trades certificate or diploma	0.703	0.972	0.523	1	0.470	2.020	0.300	13.587
Some undergraduate coursework + Undergraduate degree (e.g., B.A., B.Sc.)	-0.212	1.017	0.044	1	0.834	0.809	0.110	5.929
Graduate degree (e.g., M.S., M.A., M.B.A., M.D., Ph.D.)	0.916	0.559	2.683	1	0.101	2.499	0.835	7.478
Knowledge of the food system: Excellent and very good			3.828	2	0.147			
Knowledge of the food system: Good and fair	0.121	0.941	0.016	1	0.898	1.128	0.178	7.134
Knowledge of the food system: poor and unfamiliar with the term	1.024	0.963	1.131	1	0.288	2.784	0.422	18.379
Female	-0.063	0.595	0.011	1	0.915	0.939	0.293	3.012
Income: less than \$49,000			5.078	2	0.079			
Income: between \$50,000 and 99,999	-1.653	0.742	4.963	1	0.026*	0.192	0.045	0.820
Income: \$100,000 or more	-0.387	0.541	0.511	1	0.475	0.679	0.235	1.962

\*Denotes significance.

Dependent variable is 'agree' to the statement "Overall, my feelings towards yeast-derived agriculture are positive."

Two participants indicated 'prefer not to say' for gender and were not included in this regression analysis

TABLE 5 Response (% and n) to question "I would be more likely to consume yeast-derived dairy if it..."

Statement	%	(n)
Provided environmental benefit	61.7	71
Improved animal welfare	60.0	69
Provided dietary or health benefit	49.6	57
Was cost saving	39.1	45
There was no discernible difference in taste or mouthfeel compared to animal-derived dairy	33.4	39
Other	32.2	37

(Table 4). Adjusting for all other predictors (gender, knowledge of food systems, education), this analysis showed that being 35 years of age or older, and being vegan, were negatively associated with having positive feelings towards yeast-derived agriculture (chi-square (10) = 29.086,  $p = 0.001$ ). Being age 35 years or older had the odds-ratio of 0.151 (95% CI: 0.045, 0.499) and being vegan had the odds-ratio of 0.344 (95% CI: 0.125, 0.943). Furthermore, individuals in this pilot study with a household income between \$50,000-99,999, compared with individuals with household income of \$49,999 or less, were also negatively associated with having positive feelings towards YDA and had an odds-ratio of 0.192 (95% CI: 0.045, 0.820).

### 3.5. Factors contributing to consumption of yeast-derived dairy

Survey respondents were asked to complete the following sentence "I would be more likely to consume yeast-derived dairy if it..." and they were able to choose more than one option (Table 5). From these responses, we can see that taste and mouthfeel were not as important as other factors such environmental benefit or animal welfare.

Survey participants who selected "other" were able to leave a comment about what factors they saw as influencing their decision to consume YDD. The comments made by survey respondents ranged but were predominantly concerned with issues related to diet and to health and safety. For example, one person wrote "[If] I felt confident that it is a safe substitute from a personal health perspective; that it does not have some potential negative health impact."

A small handful of respondents indicated that they would likely consume YDD if it was vegan. For example, one person wrote "[If] it did not involve animals at all (including breeding, housing, and slaughtering them to collect their proteins)." Comments like this indicate the possibility that some participants may either be misinterpreting the information provided about the YDD production process, or may be holding on to preconceived ideas despite that information. To recapitulate, YDD is made via a process of fermentation using recombinant microorganisms inserted with 3D printed bovine DNA that produces casein and whey milk proteins; animals do not need to be raised specifically for this process.

Some respondents in this pilot study indicated under “other” that they would be more likely to consume YDD if the taste and experience of it were either similar or better than current animal-derived dairy, despite this having been an answer option to select. Others indicated that they would “...never consume food grown in a lab,” and another wrote that they would be likely to consume YDD, “If the technology and its profits could have equitable benefits and not just profit increases for large agri-food companies.”

Only one person indicated that they would consume YDA if it “Did not involve genetic modification,” while another person indicated they were “wary of cellular level interventions” because of its similarity to genetic engineering. Instead, a majority of participants in this pilot study focused on YDA as a processed food. For example, one person wrote “I do not think I’m interested at all. I prefer to eat food that is more whole grains/veg/fruit/etc. and less processing... I just do not think we need to be ‘producing’ fake dairy in a lab,” indicating that some individuals viewed this more as a processed food rather than as a genetically modified organism (GMO). The theme of processed foods emerges again in the following section.

Our pilot study results echo the findings from the meta-analysis of Bryant and Barnett (2020). They note that perceived benefits of cultured meat and cellular agriculture technologies include benefits to the environment and animal welfare, health and food safety as well as potential to increase global food supply. Despite the numerous perceived benefits, they note there still exist numerous possible barriers to acceptance including concerns regarding price, safety, feelings of disgust and unnaturalness, as well as food neophobia.

### 3.6. Additional comments on the topic of yeast-derived agriculture

Survey respondents were asked to express any comments, questions or concerns regarding cellular agriculture and or yeast-derived dairy that they may have had but were not previously addressed in the survey.

Only a handful of comments from participants in this pilot study were overly positive about YDA, with some saying they were excited and eager to purchase it, while some were positive, but said they would likely only consume it if it were lactose or allergen free. The majority of comments were from respondents indicating that they would not be interested in consuming YDA. Many of these comments indicated they did not like the concept of YDA because they viewed it as a highly processed food. As one person wrote “It sounds weird and highly processed.” And another wrote “I am on a whole plant based diet and do not eat processed food if I can avoid it.” Therefore, it appears that YDA was perceived by survey respondents as a processed food, rather than a natural, or whole food like dairy milk, despite being biologically equivalent. This finding was surprising as we had anticipated arguments against YDA to be related to associations between GMOs and cellular agriculture technologies, despite the products themselves containing no GMOs (Milburn, 2018).

Many respondents in this pilot study had mixed feelings about YDA. For example, one person wrote:

“It feels “icky” to me, perhaps in the same way that any new technology feels unfamiliar/scary to somebody who doesn’t know much about it, or what it’s capable of. If the technology is used

responsibly, doesn’t have any terrible unintended consequences, or end up causing cancer or something, then it could be a great alternative (from an animal welfare standpoint) to existing dairy products.”

Although they felt that YDA was “icky,” the respondent indicated that they could warm up to the idea given the right circumstances. This was noted several times in the responses with individuals liking the idea or one aspect of YDA but being uncertain about another aspect about it. Often participants were concerned about health implications, ethical treatment of animals involved, and environmental implications. For example,

“... If I didn’t have an allergy, I would definitely be more interested in eating yeast-derived dairy than animal-derived [sic] dairy, mainly for environmental reasons...”

“My main concern is that there would still be animals bred raised and kept in order to have access to proteins...”

Some respondents in this pilot study appeared to be ambivalent about YDA, seeing both the positive and negative aspects of it. For example, one respondent said, “I do not yet have a strong opinion about it, but it seems like a more realistic prospect (with fewer ethical questions) than cellular meat production.”

Other respondents indicated that they had questions regarding the process of YDA, with some comments indicating that the process was not fully understood, despite having been provided with information about the process during the survey (see [Supplementary information](#)). For example, one person wrote “If it does not have the side effects of yeast,” despite no yeast being in the final product. Another person wrote, “Many questions regarding how the base materials ie. stem cells are produced,” and “Will the products be cholesterol free? How will the animals from whom the cells are taken be maintained?” In addition to this, some participants in this pilot study noted that they simply did not have enough information to make an informed decision.

Another theme that emerged was regarding the topic of agriculture and farming practices. Some participants wrote that they did not think YDA was the right direction in which agriculture should go. Rather, there was a desire to shift focus towards natural foods and sustainable agriculture, and to move away from industrial agriculture. For example, one person wrote, “The best good for humans is made by nature. Please get our agricultural system back to growing health food, using sustainable practices.” Another wrote, “This seems like an unnecessary innovation when we COULD be simply creating agricultural policies for healthier farms integrated into living and built environments.”

Environmental concern was also present in these comments, sometimes in the context of agriculture policy like the quote above, or others expressing uncertainty regarding the environmental impacts of YDA. Some indicated they wanted long-term studies on how it impacts the environment and soil conservation. For example, one person wrote: “If we had studies on the long term effects it has on the environment, and if I knew more about the manufacturing process- are the materials for the equipment sustainable? Or are we taking one problem and trading it for another at the expense of our dairy farmers’ livelihoods?...”

Lastly, three separate respondents indicated this was a product more suited to non-vegans than vegans. Surprisingly, only one person indicated the need for labeling YDA products.

### 3.7. Vegan perception and acceptance of YDA and YDD

Our pilot study indicates that vegans may be less likely to try or purchase yeast-derived dairy products and may be less likely to replace or incorporate them into their diet compared with non-vegans. We saw this indicated in responses to multiple questions across the survey. Although vegan participants agreed that YDA would have positive impacts on the environment and for animals, they did not view YDA as being animal-free or vegan. Furthermore, they did not see it as something which would have positive impacts on the health and well-being of humans. Our pilot research is consistent with other cellular agriculture research, specifically with regards to cultured meat, which has observed that vegans and vegetarians were less likely to try or purchase these products compared with meat eaters (Bryant and Barnett, 2018; Bryant et al., 2019). As noted by Hopkins (2015), vegans and vegetarians are the recipients of a disproportionate amount of media attention on the subject of cellular agriculture. Further research with larger sample sizes is needed to gain more understanding of whether vegan response to YDD does indeed mirror their response to cultured meat.

While our pilot study results indicate that vegan respondents did not consider YDD to be vegan, this contradicts the claims of YDD producers. Perfect Day uses the term “animal-free” in much of its marketing, and in the FAQ section of its website, there is a question “Is your protein vegan?” to which Perfect Day has posted the response “Yes! Flora-made dairy protein is made without the use of animals and zero compromise on taste and nutrition. Our animal-free dairy protein is completely vegan as well as lactose-, hormone-, and antibiotic-free.” The answer to the FAQ goes on to state, “However, because it’s identical to the proteins from cows, it does contain milk allergens, which are labeled on products made with Perfect Day, “Contains: Milk Protein” (Perfect Day, 2020a). In the absence of laws or other means of regulating what can and cannot be labeled “vegan,” this tension between vegan consumer perception and corporate claims is likely to continue.

## 4. Conclusion

Yeast-derived agriculture allows for the production of dairy products which are not derived from animals. Our pilot study provides preliminary insights and suggests directions for future research into how these novel foodstuffs may be received by consumers, in particular vegan consumers; consumer attitudes toward YDD will play a significant role in what impacts these products have on dairy farmers and processors. Our team has also surveyed and interviewed dairy industry stakeholders as part of this area of research; those results form the basis of an article in preparation.

The results of our pilot study suggest that there is a good deal of interest in both trying and purchasing yeast-derived dairy. Our preliminary findings indicate that consumers are unlikely at this point in time, however, to incorporate these products into their daily routines or replace their current option entirely. This reluctance may be overcome, or at least reduced, when the product becomes available

for purchase or more information is readily available on the topic of cellular agriculture technologies.

Furthermore, our pilot study indicated that participants who are vegans, and individuals 35 years of age or older are also less likely to try yeast-derived agriculture products, as indicated by the binary regression analysis where being vegan or being over the age of 35 had decreased odds of having positive feelings towards YDA. Limitations of this pilot study include having a small sample size; also, the narrow demographics we chose to study make extrapolation of our findings to the wider population difficult. This pilot study, however, lays the groundwork for a larger national survey which will be disseminated to a wider, more demographically diverse audience, or for additional studies targeting larger groups of particular segments of the population (e.g., vegans).

Some of the survey comments suggested that there may be confusion or misinterpretation regarding how YDD is made, even after a detailed explainer was provided; alternatively, survey respondents may have been holding on to preconceived biases. Further research on this topic may need to go to greater lengths to explain the process as part of engaging with study participants and to account for bias. Similar to the findings from Broad et al. (2022) the results from this pilot study suggests that any company wishing to sell this product in British Columbia, and likely other areas as well, will have to do extensive marketing and education campaigns to not only inform consumers of what it is, but also to inform consumers about its safety for those with allergies and other dietary restrictions. While our research provides data linking demographic characteristics to perceptions of and willingness to try, it also indicates this data may be shaped by perceptions of cellular agriculture that do not align with the framing of the YDD production process by the industry. Our pilot study indicated that vegans are less likely to consume the product than non-vegans, in part because they do not perceive it as being vegan, which contradicts claims made by Perfect Day and other companies. In the absence of some sort of international arbiter of the vegan label, it is unclear how these contradicting views may be resolved.

Despite questions and reservations on the part of consumers, companies bringing YDD products to grocery stores and to online retailers are unlikely to slow their pace. As they become more available, ongoing research about perceptions and acceptance toward these products will be necessary to understand the role they are playing in both diets and food systems as a whole. In particular, surveys of broader audiences will provide key sources of data on how YDD is being received.

## Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

## Ethics statement

The studies involving human participants were reviewed and approved by University of the Fraser Valley Human Research Ethics Board, protocol #1156G-19, on April 18th 2019. The patients/participants provided their written informed consent to participate in this study.



## Author contributions

ZM-Z performed data collection and statistical analysis. LJP and ZM-Z drafted the manuscript. LLN supervised the project. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2023.1127652/full#supplementary-material>

## Appendix

TABLE A1 Chi-Square test statistics examining differences in responses between vegans and non-vegans for likelihood to try, incorporate and replace milk or cream and ice cream with yeast-derived dairy alternatives.

Food type		Pearson Chi-square	df	p value	Cramer's V
Milk or Cream	Try	2.777	1	0.096	0.156
	Purchase	1.561	1	0.211	0.118
	Incorporate	2.114	1	0.146	0.137
	Replace	6.973	1	0.008*	0.248
Ice cream	Try	3.877	1	0.049*	0.184
	Purchase	2.195	1	0.138	0.139
	Incorporate	3.736	1	0.053	0.183
	Replace	8.755	1	0.003*	0.280

\*Denotes significance.

TABLE A2 Mann–Whitney tests for perceptions and attitudes toward yeast-derived agriculture.

	Mann–Whitney U	p value	Mean rank Vegan (n=44)	Mean rank non-vegan (n=71)
Yeast-derived agriculture is a technology that will have positive impacts on the environment	1,558.00	0.978	58.09	57.94
Yeast-derived agriculture is a technology that will have positive impacts on the well-being of animals	1,460.00	0.469	55.68	59.44
Yeast-derived agriculture is an environmentally sustainable alternative to traditional dairy	1,477.50	0.563	56.08	59.19
Yeast-derived agriculture is a technology that will have positive impacts on the health and well-being of humans	1,251.50	0.051	65.06	53.63
Products made using yeast-derived agriculture technologies are 'animal free'	1,172.50	0.016*	66.85	52.51
Products made using yeast-derived agriculture technologies are vegan	1,296.00	0.102	64.05	54.25
Products made using yeast-derived agriculture technologies are vegetarian	1,503.50	0.712	59.33	57.18
Overall, my feelings towards yeast-derived agriculture are positive	1,378.00	0.251	62.18	55.41

\*Denotes significance.