Consumer Preferences for Farm-Raised Meat, Lab-Grown Meat, and Plant-Based Meat Alternatives: Does Information or Brand Matter?

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Abstract
Despite rising interest in innovative non-animal-based protein sources, there remains a lack of information about consumer demand for these new foods and their ultimate market potential. This study reports the results of a nationwide survey of more than 1,800 U.S. consumers who completed a choice experiment in which they selected among conventional beef and three alternative meat products (lab-based, plant-based with pea protein, and plant-based with animal-like protein) at different prices. Respondents were randomly allocated to treatments that varied the presence/absence of brands and information about the competing alternatives. Results from mixed logit models indicate that, holding prices constant and conditional on choosing a food product, 72% chose farm raised beef, 16% plant-based (pea protein) meat alternative, 7% plant-based (animal-like protein) meat alternative, and 5% labgrown meat. Adding brand names (Certified Angus Beef, Beyond Meat, Impossible Foods, and Memphis Meats) actually increased the share choosing farm raised beef to 80%. Environment and technology information had minor effects on conditional market shares but reduced the share of people not buying any meat (alternative) options, indicating information pulled more people into the market. Even if plant- and lab-based alternatives experienced significant (e.g., 50%) price reductions, farm raised beef maintains majority market share. Vegetarians, males, and younger, more highly educated individuals tend to have relatively stronger preferences for the plant- and lab-based alternatives relative to farm-raised beef. Respondents are strongly opposed to taxing conventional beef and to allowing the plant- and lab-based alternatives to use the label "beef."

Key words: Consumer, Cell-based; Cultured; In-vitro; Demand, Labgrown meat; Meat alternatives; Plant-based meat

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Introduction

With the increasing criticism of animal agriculture, there appears to be growing interest meat alternatives. U.S. consumers are among the heaviest consumers of beef in the world, consuming 57.2 pounds per capita in 2018 (ERS-USDA, 2019), much of it in the form of ground beef. While beef burgers remain popular, consumers report in surveys a desire to cut back on their meat consumption (Neff et al., 2018). In recent years, innovative products have emerged giving consumers new protein alternatives similar to ground beef. While there was more than 20% growth in the plant-based meat category in 2018 (Plant Based Foods Association, 2018), there is still a great deal of uncertainty about consumers' preferences for these alternative products and a ample speculation about the ultimate size of this market.

There have been substantial investments in the development of plant-based and lab-grown meats in recent years. Plant-based burger patties have been developed that create a meat-eating experience designed to mimic the taste and texture of beef, going beyond the veggie-burgers of the past. These plant-based meat alternatives are now available in many grocery stores and are also appearing in major restaurant chains such as Burger King, Del Taco, and White Castle. In addition to the new plant-based burgers, several start-ups are currently developing meat by culturing animal cells, and it is likely that these lab-grown meat patties will hit the market in coming years. With burgers being one of the most popular menu items in the U.S., it is of interest to better understand how the new burgers might affect the U.S. ground beef market.

In this paper, we aim to better understand consumer acceptance, choice, and willingness to pay (WTP) for the three primary beef burger alternatives that are emerging (plant-based patty using pea protein, using animal-like proteins produced by yeast, and labgrown beef) relative to farm-raised beef, and consumer's preferences for policies surrounding these alternatives. To our knowledge, this is one of the first studies investigating U.S. consumer preferences for the new generation of plant-based burger patties. Because there is no labgrown meat yet on the market, and because plant-based burgers using animal-like heme proteins (i.e., the Impossible Burger) was only recently approved for grocery sale, there is no scanner data available for these products and thus no easily comparable consumer demand data for these beef substitutes. As such, this study conducts a discrete choice experiment in which consumers make simulated retail choices between competing products at different prices under different information and branding conditions.

To our knowledge, Slade (2018) is the only prior study eliciting preferences for labgrown meat relative to plant-based alternatives. However, this study did not discriminate between different types of plant-based meats (e.g., Beyond Meat vs. Impossible Foods) and it did not investigate the effect of information or brand on choice. Moreover the study was conducted in 2017 in Canada. As highlighted by Bryant and Barnett (2018), there is a scarcity of studies on the effect of information about environment and animal welfare on consumer acceptance of labgrown meat. In addition, while some studies investigated consumer willingness to try or purchase intentions for labgrown meat (Bryant et al., 2019; Wilks and Phillips, 2017), no study investigated the consumers' willingness-to-pay (WTP) or demand at alternative price-points in the United States.

This study addresses this research gap and investigates consumer preferences and demand for meat versus meat-like burger patties. Meat-like burger patties include made of labgrown beef, plant-based meat using animal-like heme protein, plant-based meat using pea protein, and farm raised beef using a choice experiment (CE) under different information treatments including information on the environmental impact or the technology used to produce the meat-like patties. Moreover, given the fact that these are branded products, we explore the sensitivity of choice to use of brand names used to market the beef alternatives. Finally, we also solicit respondent's preferences for different policies surrounding the alternative meat products.

Background

At the moment, several alternatives exist and are being developed to imitate the traditional beef burger patty. The new generation of meat-like plant-based burgers are gaining popularity as they are better at mimicking beef burger patties compared to the previous alternatives. One of the popular veggie burger patties is made with plant-based protein (pea protein) and beet juice resulting in a burger that 'bleeds' like a traditional beef burger (Beyond Burger©). Another new type burger uses plant-based heme as the key ingredient to create a meaty flavor and appearance (Impossible Burger©). This approach uses a genetically engineered yeast to produce soy leghemoglobin, a protein which carries heme. Heme is naturally present in conventional beef and is thought to impart a distinctive meat-like flavor. While Beyond Burger© is currently offered in grocery stores, until very recently the Impossible Burger© was only available in restaurants. In addition to these new plant-based burgers, several start-ups are currently developing a burger patty by culturing animal cells, a labgrown burger patty. For labgrown meat, stem cells of a living cow are harvested and nurtured to create muscle tissue in the lab. Labgrown meat is not yet available to consumers as the technology remains cost prohibitive, but it is expected to become available in the coming years.

Next to the challenge of the technical feasibility to successfully producing large quantities of affordable labgrown meat, another major challenge is consumer acceptance of the novel products. Whether these burger will become successful on the market depends on whether consumers will adopt a labgrown nor new plant-based burgers in their diet. Consequently, it is important to study consumers preferences for alternative meat products. Several studies have evaluated consumer acceptance of labgrown meat (Bryant and Barnett, 2018; Mancini and Antonioli, 2019); however only two included a U.S. sample (Bryant et al., 2019; Wilks and Phillips, 2017) and no study investigated consumers' willingness to pay (WTP). Wilks and Phillips (2017) reported that 31% of U.S. consumers definitely and 34% probably would be willing to try labgrown meat. While this study shows that 65% of U.S. consumers are willing to try the novel food product, the study also found that only one third would willing to eat it regularly. Similarly Bryant et al. (2019) reported that 29.8% of U.S. consumers indicated they were very or extremely likely to purchase labgrown meat. Slade (2018), using a choice experiment in Canada, compared market shares for different types of burgers when all were prices $4, and reported a 65% market share of beef burger, 21% for plant-based and 11% for labgrown burgers (and 4% would buy none). However, no study to our knowledge has evaluated potential market shares under varying information or brands.

Consumer acceptance of these novel products will determine market potential, and consumers might be influenced by information about the products. Information has been shown to affect consumer acceptance of food produced with novel technologies. This is also true for the affect consumer acceptance of labgrown meat (Hocquette et al., 2015; Siegrist et al., 2018; Verbeke et al., 2015). For example, Verbeke et al. (2015) reported that a quarter of the Belgian consumers said they were willing to try labgrown meat, a figure which increased to 43% following the provision of additional information about the benefits of labgrown meat. However, Hocquette et al. (2015) reported lower acceptancy rates. Only 9 to 19% of the participants who received information about the problems faced by the meat industry and the potential benefits of labgrown meat believed that labgrown meat would be accepted by consumers (Hocquette et al., 2015). Swiss consumers receiving non-technical descriptions on the production of labgrown meat production had a higher willingness to purchase labgrown meat compared to those receiving more technical descriptions of cultured meat (Siegrist et al., 2018). Studying as ample of Dutch students, Bekker et al. (2017) compared the effect of negative and positive information about labgrown meat on the explicit attitude towards labgrown meat. They found that positive (negative) information leads to a more positive (negative) explicit attitude towards labgrown meat. These studies illustrate the importance of the information provided to consumers on acceptance of labgrown meat. Bekker et al. (2017, p 253) even concludes that information provision about cultured meat could “play a role in the commercial success of cultured meat”.

With conventional beef being resource-intensive, requiring significant amounts of water, land and other resources, it is argued that plant-based and labgrown alternatives have significantly lower environmental impacts (Heller and Keoleian, 2018; Tuomisto, and Teixeira de Mattos, 2011). Producers of plant-based meat alternatives (using pea protein as well as using animal-like protein produced by yeast) already communicate the environment benefits to consumers information (Beyond Meat, 2018; Impossible Food, 2018). It is expected that labgrown meat producers will do the same when their products become available on the market. We experimentally test the effect of highlighting the benefits through information provision to consumers.

Procedures

Because plant-based burger using heme protein produced by yeast and labgrown burgers are not available yet in the supermarket, there is no grocery scanner data available on consumer demand for these burger patties. Consequently, this study addresses this gap and elicits consumer preferences using a U.S. nationwide survey. Consumer preferences are elicted using a discrete choice experiment (DCE) approach, which has been extensively used in meat demand analysis (Lusk and Schroeder, 2004; Lusk and Tonsor, 2016; Scarpa et al., 2013; Van Loo et al., 2014).

In the DCE, respondents were asked to make repeated choices between four burger patties offered at different price levels. The four burger patties are: labgrown beef, plant-based meat animal-like heme protein, plant-based meat using pea protein, and farm raised beef. These options were priced a six price levels ranging from $2.99/lb to $10.49/lb in $1.50 increments. This price range was selected to encompass the averages prices for ground beef from the US Bureau of Labor Statistics (2019) as well as the prices for plant-based and beef burgers in actual stores.

We used a labelled DCE design, meaning all choices had four alternatives corresponding to the different meats (plus a "none" alternative) at different prices. Given our experimental setting, there are 1,296 (6^4) possible choice questions including every product type at every price level. To reduce the number of choice options, we utilized an orthogonal fractional factorial design (see Louviere et al., 2000) and reduced the number of choice questions to 36, which were then further reduced to 9 per respondent using blocking techniques (4 blocks). Participants were randomly assigned to one of the four blocks and answered nine choice questions, the order of which was randomized. Each choice question included a non-purchase (opt-out) alternative and four meat products or meat replacers offered at different prices.

In addition to assessing consumer valuation for alternative meat products, this study uses a between-subject approach to also examine the effects of brand and various information types on consumer preferences for alternative meat products. A total of four treatments were implemented (see Table 1).

<< Insert Table 1>>

Treatment 1 is the control treatment ("Control"). Respondents were not provided any information about the alternatives, which were only described/labeled using a few words. Treatment 2 ("Branding"), accounted for the effect of brand names, which likely mimics the retail environment consumers are likely to face. The four selected brands are Memphis Meat, Beyond Meat, Impossible Foods, and Certified Angus Beef. These brands were chosen as they are the most known brands for each of the respective products in the U.S. Figure 1 shows the product presentation for the branded and non-branded treatments.

<< Insert Figure 1>>

Producers of plant-based meat alternatives (using pea protein as well as using animal-like protein produced by yeast) provide consumers with information about the environmental and animal welfare benefits of their products as compared to conventional meat (Impossible Food, 2018; Beyond Meat, 2018) via advertisements, website, in-store flyer, in-restaurant fliers, etc. In order to test for the effect of these communication messages on consumer preferences for meat alternatives, Treatment 3 ("Sustainability"), gave respondents environmental and animal welfare information that originated from the companies selling these products. More specifically, we showed the reduction in water use, land use, energy use and greenhouse gas (GHG) emissions associated to each of the three beef alternatives compared to conventional beef, based on literature (Heller and Keoleian, 2018; Tuomisto and Teixeira de Mattos, 2011) and company claims. Finally, Treatment 4 ("Technology"), includes information about the technology used in the production of the different products, which enables a test of whether additional information on the production of the meat alternatives has an effect on consumer preferences. Figure 2 shows the information given in Treatment 3 and 4.

<< Insert Figure 2>>

After the DCE, respondents were asked several policy-related questions. First, respondents were asked, “Should the following products be allowed to be labelled as ‘beef’?” for three alternatives: labgrown meat, plant-based meat using pea protein, and plant-based meat using animal-like proteins produced by yeast. There were two response options: “Yes, it should be allowed to be labelled as ‘beef’” or “No, the USDA and FDA should prohibit the use of the word ‘beef’ on the labels for these products.” Respondents were then asked two stand-alone questions. The first was, “Would you support or oppose a 10% tax on beef from cattle in an effort to reduce beef consumption for environmental and animal welfare objectives?” The second question was, “Would you support or oppose a policy that would require that any product labeled as “beef” come from cattle that have been born, raised, and harvested in the traditional manner, rather than coming from alternative sources such as a synthetic product from plant, insects, or other non-animal components and any product grown in labs from animal cells?” Response categories for these two questions were simply “Support” or “Oppose.”

Data Analysis

DCEs are consistent with random utility theory (McFadden, 1973). Within this framework, consumer *n* is assumed to derive the following utility from choice alternative, *j*: $U_{nj} = V_{nj} + \varepsilon_{nj}$; where V_{nj} is the systematic component of the utility function, and $\varepsilon_{\mathrm{nj}}$ is the random or unobservable component. V_{nj} is defined as:

$$(1) \quad V_{nj} = \beta_j + \alpha \, Price_{nj},$$

where β_j is an alternative-specific constant indicating utility for alternative/brand *j* relative to the opt-out option, which is normalized to zero for identification purpose, α is the marginal utility of price, and $Price_{nj}$ is the price of alternative *j* faced by consumer *n*.

The data are analyzed using a random parameter logit (RPL) model, which accounts for taste variation across consumers. Accordingly, the coefficients in (1) were assumed random following empirically plausible statistical distributions. The alternative specific constants were specified as random following a normal distribution because it is expected that individuals can exhibit either positive or negative values or preferences for the beef products. The price coefficient is assumed to follow a constrained (one-side) triangular distribution. The use of a constrained triangular distribution has been supported by a number of authors (Alfnes, 2006; Hensher and Greene, 2003; Scarpa et al., 2013) due to its finite range of variation (Hensher, Rose and Greene, 2015), which rules out positive price coefficients (i.e., demand curves are forced to slope downward). Formally, in the RPL, the unconditional choice probabilities of individual *n* choosing alternative *j* is expressed as follows:

$$(2)\ \{P_{nj}\} = \int_{\tilde{\beta}_n}\int_{\tilde{\alpha}_n}\prod_{t=1}^{T}\frac{V_{njt}}{\sum_j e^{V_{njt}}} f\left(\tilde{\beta}_n, \tilde{\alpha}_n|\mu, \Omega\right) d\tilde{\beta}_n d\tilde{\alpha}_n$$

where $f\left(\tilde{\beta}_n, \tilde{\alpha}_n|\mu, \Omega\right)$ is the probability density function of the vector of J random coefficients $< \tilde{\beta}_n, \tilde{\alpha}_n >$; μ is the vector of the price coefficient and the alternative-specific constants; Ω is the variance-covariance matrix of the vector of random parameters, for which we assume the off-diagonals are zero. The models were estimated by simulated maximum likelihood estimation techniques using 500 Halton draws (Train, 2009). The normally distributed coefficients provide information on the proportion of the population that attach a positive value to the product (Train, 2009). We calculate the share of the population with positive and negative values for each product.

Further, based on the RPL estimates, we also calculated the predicted conditional (conditional on buying an option) and unconditional market share for each meat product or meat alternatives, following Lusk and Tonsor (2016). We did so by substituting the estimated coefficients from the RPL into probability equations, setting all prices equal to \$5.00/lb. This allowed us to explore the market shares of the meat alternatives across different information treatments when all prices are held constant. In addition, following Lusk and Tonsor (2016), the predicted unconditional market shares were also used to derive the demand curves of each meat type across treatments. Based on equation (2), the demand curves were derived by substituting the estimated coefficients into probability equations with the prices of all meat products set to $5.00/lb, except for the product of interest whose price levels were set at successively higher or lower price levels. We can also use the estimated coefficients, along with each individual's choices, to calculate "individual specific" coefficients (Train, 2009). We use these "individual specific" coefficients to calculate predicted market shares for each respondent and then use ordinary lease squares regressions to determine how these shares vary with socio-economic and demographic characteristics.

Results and Discussion

The data were collected through a nationwide online survey conducted among U.S. food shoppers in December 2018 and January 2019. The survey was programmed in Qualtrics and participants were recruited by a market research agency. TIn total, 1,830 completed responses were collected. Appendix table A1 shows the characteristics of the sample. The gender, age, income, region of residence, and race/ethnicity are similar to the US population.

Table 2 reports the RPL estimates for each of the four treatments: Control, Branding, Sustainability, and Technology (note: summary statistics for choices of each alternative in each treatment are provided in appendix table A2 and multinomial logit estimates that assume preference homogeneity are in appendix table A3). A likelihood ratio test of the null hypothesis that coefficients are equal across treatments, conducted by comparing the sum of the estimates from each treatment to the pooled model, yields a chi-square value of 6,200 with 27 degrees of freedom. The null is rejected at the $p<0.01$ level, indicating information and/or brands significantly affected the parameter estimates. For each treatment and product type, the price coefficient is negative and statistically significant indicating a decrease in utility with increasing price. The estimated coefficients of the alternative specific constants indicate the utility of each meat type relatively to the opt-out option. The coefficients for Beef, Plant-Pea, and Plant-Yeast are statistically significant and positive, meaning that holding price constant, people prefer buying one of the meat products that nothing at all.

More specifically, farm raised beef is the most preferred followed by the plant-based alternatives using pea protein and heme produced by yeast. On the other hand, the coefficient on Lab, referring to labgrown meat, is not statistically significant from zero in all four treatments. This indicates that, on average, the utility for the labgrown meat does not statistically differ from the no-buy option. However, the estimated standard deviation around the mean preference for labgrown meat is large, significant preference heterogeneity in the population. For example, in the control treatment, the coefficient lab has an estimated mean of -0.25 and estimated standard deviation of 3.75, indicating labgrown meat preferred to "none" by 47% of consumers and avoided by the other 53%.

<< Insert Table 2>>

Following Scarpa and Del Giudice (2004) and Caputo et al. (2018), we calculated the share of the population with positive preferences for each of the products (Table 3). Providing information has only a relatively small impact on the proportion of consumers with a positive value for labgrown meat. While providing the brand name increases the share of consumers with positive preferences for labgrown meat from 47% to 53%, providing sustainability information results in the largest increase to a total of 56% of consumers with positive preferences. For the plant-based alternatives, much larger shares of consumers have positive preferences relative to "none", with over 8 out 10 consumers attaching a positive value to these plant-based alternatives. This share reduces when brands or technology information is presented.

<< Insert Table 3>>

Table 4 reports the mean WTP values for the various meat alternatives across treatments. The farm-raised beef burger the largest mean WTP (relative to "none") ranging from \$9.24 to \$11.35/lb, while labgrown meat has the lowest mean WTP. Comparing treatment 1 with treatments 3 and 4 reveals that providing of sustainability information leads to a higher mean WTP for the plant-based alternatives while providing information on the technology reduced their mean WTP values. This result shows that it is beneficial for providers of the new alternatives to provide consumers with the information on the environmental benefits of plant-based meat alternatives as it increases the WTP but some of that effect is offset when consumers learn more about the underlying technologies used to produce the patties.

<< Insert Table 4>>

Figure 3A shows the unconditional predicted market shares for the different meat alternatives across treatments when all products are priced at $5/lb. When no information is given, the market share of farm-raised beef is 63%, while the plant-based using pea protein and plant-based using animal-like proteins produced by yeast options have choice shares of 14% and 7% respectively. Labgrown meat has the smallest share (4%). By providing brand names, the share of consumers choosing farm raised beef increases to 72%. Proving environmental information increases the choice share for labgrown and plant-based using pea protein to 6% and 16% respectively, while the share of plant-based using animal-like proteins produced by yeast remains unchanged. Technological information results in a 7% share for labgrown meat and 10% for both plant-based alternatives. This illustrates that providing information has only a small effect on the market shares of the various meat alternatives. Additionally, in the Technology treatment, where people were informed that the plant-based burger patty using animal-like proteins are produced by a GM yeast, had only minor effects on the choice share (control 7%, T4 10%).

Figure 3B shows the market shares of the different products, conditional on consumers choosing one of the products. In the control condition, the market share for conventional beef was 72%. These market shares are in line with Slade (2018) who reported a market share of 67% for beef, 21% for plant-based eat and 11% for labgrown meat. Interestingly, looking at the market share associated with the "none" option, and comparing figures 3A and 3B, it seems that providing information pulls consumers from "none" into the plant-based products rather than from beef to these products. This may suggest information may attract new consumers into the market of "burger consumption" rather than reducing beef consumption *per se*. Further, looking at Figure 3B, it can be noted that conditional on people choosing to buy a product, providing information has little effect on the predicted market shares. This reinforces the idea that, regardless of the type of information about meat alternatives retained by consumers, plant- and lab-based meat alternatives do not appear to significantly replace farmed raised beef at the present time.

<< Insert Figure 3>>

To explore how the market share would change when the product prices vary, demand curves were estimated using the RPL model estimates in Table 2. Figure 4 illustrates the implied demand curves for each meat (alternative) product across the four treatments, which were constructed over the range of prices used in the experimental design ($3 to $10.50/lb). Figure 5 reports the implied demand curves for the four alternatives within each treatment group.

<< Insert Figure 4>>

Providing consumers with additional information about the technology used to produce and the environmental impact of labgrown meat results in slightly higher market shares, but there are no marked differences between the demand curves in the control and Branding treatment. This evidence is not surprisingly as the brands of labgrown meat are relatively new in food markets, while consumers who are more concerned about the sustainability issues may be more willing to purchase labgrown meat. Conversely, branding seems to drive demand for farm raised beef as illustrated by the shift in demand of farm raised beef when brand names are provided to consumers. The farm-raised beef demand curves for the other information treatments (T3 and T4) produce the most conservative market share estimates and they coincide with prices below $4.5. Interesting results emerge for the plant-based meat alternatives. To illustrate, in the case of plant-based meat using animal-like proteins produced by yeast, the demand curve from the technology treatment implied higher market shares than the control, while the demand curves from the other treatments (branding, and sustainability) tend to nearly coincide for all prices with the demand curve in control condition. For the plant-based meat alternative using pea protein, on the other hand, providing consumers with sustainability information implied slightly higher market shares than in the control treatment, while technological information reduces the market shares and branding results in the most conservative market share for the plant-based alternative with pea protein.

Looking at the demand curves grouped per treatment (Figure 5), it can be seen that for each treatment, the demand for the three alternatives is relatively close to each other while the demand for farm raised beef is much larger.

<< Insert Figure 5>>

For the Control treatment (T1) as well as the Sustainability (T3) treatment, plant-based using pea protein has a higher market share as compared to the other meat alternatives. Labgrown meat and plant-based using yeast only differ in these treatments (T1 and T3) in market shares at low prices. In the Branding (T2) and the Technology (T4) treatment, the demand curves for two plant-based meat alternatives coincide while the labgrown meat has a slightly lower demand.

Table 5 reports the relationship between demographics and "individual specific" market shares, assuming all products are equally priced and respondents choose one of the four alternatives. Unsurprisingly, vegetarians are significantly more likely to choose one of the plant- or lab-based alternatives. Compared to meat-eaters, the market share for lab-based, plant-based using pea, plant-based using animal-like proteins is 4.3, 28.2, and 17.1 percentage points higher, respectively for vegetarians. Results also show consumers with a college degree and men are more likely to choose the non-beef alternatives. Older consumers were more likely to choose farm-raised beef and less likely to choose the plant- and lab-based meats relative to younger consumers. The quadratic term suggests the age effect is most pronounced for the youngest consumers in the sample. Income, region of residence, and treatments had no significant effect on the conditional market shares.

<<Table 5>>

Table 6 shows consumers' policy preferences. The results show strong opposition to using the word "beef" on any of the alternative meat products and support for regulating the term to only apply to farm-raised animals. Specificity, more than 70% of the respondents support that USDA and FDA prohibit the word "beef" on the packaging of meat alternatives. The results also show less than a third of respondents were supportive of a 10% tax on farm-raised beef to address environmental concerns.

<<Table 6>>

Conclusion

With new plant-based meat alternatives that better mimic meat better and the development of labgrown meat, it is important to better understand consumers' preferences for these alternatives. This study provides insights to better understand current consumers preferences for these alternatives vis-a-vis farm-raised meat. Because the new alternatives are being marketed by start-up companies with a strong interest in touting the benefits of their products, we tested the impact of different information and the presence of brands on choice.

Overall, we find that information has only small impact on consumer choice. Providing information on environmental and animal welfare benefits of the meat alternatives has the largest effect on the share of consumers with positive preferences for labgrown, plant-based using pea protein and using animal-like proteins produced by yeast, respectively. Including brand names tended to increase the share of consumers choosing conventional beef, when conventional beef was branded as Certified Angus Beef. While market shares, conditional on choosing a product, were relatively unaffected by information, we found that information tended to reduce the share of consumers choosing "none." These findings suggest that increasing concerns about environment or animal welfare benefits, rather than damaging conventional meat demand, might rather pull more consumers into the market for plant- and lab-based alternatives. When looking at differences in preferences across various demographics, we found that vegetarians, males, and younger, more highly educated individuals tend to have relatively stronger preferences for the plant- and lab-based alternatives relative to farm-raised beef.

There has been much debate with respect to labeling of plant-based and labgrown meat. While some stakeholders such as Memphis Meats and North American Meat Institute (2018) refer to"'cell-based meat and poultry," others (e.g., the US Cattleman's Association (2018)) believe food can only be labelled as meat when harvested from animals raised in the traditional matter. The latter groups argue consumers might be misled or confused when products that do not come from slaughtered animals are labeled as 'meat' (US Cattlemen's Association (USCA), 2018). Our study provides insights into the consumer perspective of the current debate on whether meat alternatives should be labelled as "meat." We find respondents are strongly opposed to allowing the plant- and lab-based alternatives to use the label "beef." In addition, most consumers would support a policy that would require that any product labeled as "beef" come from cattle that have been born, raised, and harvested in the traditional manner, rather than coming from alternative sources such as a synthetic product from plant, insects, or other non-animal components and any product grown in labs from animal cells.

Overall, this study shows most consumers strongly prefer conventional beef to the alternatives. Not only is lab-based beef the furthest from being technological and commercially feasible, it is the least desirable of the products studied. Plant-based meat using pea proteins (i.e., Beyond Meat) was the most popular non-animal alternative followed by plant-based meat using animal like protein from yeast (i.e., Impossible Foods). Due to the novelty of these products, it is possible that these preferences can change, particularly when more consumers are able to taste them. However, at present, the future market potential for these products appears to fit more in the "niche" category, even at significant price discounts. With more plant-based alternatives coming to market and consumers becoming more familiar with these products and with the respective brands, it remains interesting to see whether the demand for these products change as more alternatives become available at the food service and retail level and consumers become more familiar with the alternatives to conventional beef.

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Table 1. Information treatments

Treatment	Description	Treatment name
1	Only DCE questions	Control
2	DCE questions + Brand names	Branding
3	DCE questions + Environmental information	Sustainability
4	DCE questions + Technological information	Technology

Table 2. Random Parameter Logit Model Estimates by Treatment

		Treatment 1 Control	Treatment 2 Branding	Treatment 3 Sustainability	Treatment 4 Technology	Pooled
Lab[a]	Mean	-0.25	0.25	0.58	0.22	1.10*
		(0.47)[c]	(0.34)	(0.53)	(0.32)	(0.17)
	St.Dev.	3.75*[d]	3.62*	3.89*	4.63*	3.18*
		(0.33)	(0.50)	(0.44)	(0.33)	(0.18)
Plant-pea[a]	Mean	3.00*	1.75*	3.11*	2.13*	2.63*
		(0.30)	(0.26)	(0.30)	(0.22)	(0.13)
	St.Dev.	3.20*	3.34*	3.46*	3.68*	2.39*
		(0.34)	(0.23)	(0.42)	(0.31)	(0.10)
Plant-yeast [a]	Mean	2.10*	2.07*	2.61*	2.26*	2.41*
		(0.28)	(0.24)	(0.26)	(0.25)	(0.15)
	St.Dev.	2.33*	3.19*	2.12*	3.43*	2.27*
		(0.20)	(0.34)	(0.16)	(0.37)	(0.22)
Beef [a]	Mean	7.33*	8.27*	7.06*	7.68*	6.69*
		(0.31)	(0.41)	(0.28)	(0.41)	(0.18)
	St.Dev.	4.72*	4.02*	3.60*	4.33*	4.70*
		(0.28)	(0.25)	(0.26)	(0.22)	(0.23)
Price[b]	Mean	-0.72*	-0.76*	-0.68*	-0.68*	0.66*
		(0.04)	(0.04)	(0.03)	(0.04)	(0.20)
	St.Dev.	0.72*	0.76*	0.68*	0.68*	0.66*
		(0.04)	(0.04)	(0.03)	(0.04)	(0.20)
# parms		9	9	9	9	9
Log likelihood		-3146	-3084	-3316	-2961	-12646
N choice		4149	4266	4077	3978	16470
N people		461	474	453	442	1830
AIC		6310.3	6187	6650	5941	25310
AIC/N		1.521	1.450	1.631	1.494	1.537

[a] Parameters are normally distributed
[b] Parameters are distributed as one-sided triangular
[c] Numbers in parentheses are standard errors
[d] One asterisk signifies statistical significance at the 0.05 level or lower
Note: A likelihood ratio test of the null hypothesis that coefficients are equal across treatments yields a chi-square value of 6200 with 27 degrees of freedom; the null is rejected at the $p<0.01$ level.

Table 3. Proportion of positive preferences for each of product based on the RPL model

	Treatment 1 Control	Treatment 2 Branding	Treatment 3 Sustainability	Treatment 4 Technology
Labgrown	47.3%	52.8%	55.9%	51.9%
Plant-based using pea protein	82.6%	70.0%	81.6%	71.9%
Plant-based using animal-like proteins produced by yeast	81.6%	74.2%	89.1%	74.5%
Farm raised beef	94.0%	98.0%	97.5%	96.2%

Table 4. Mean WTP Estimates based on the Random Parameter Logit Models

	Treatment 1 Control	Treatment 2 Branding	Treatment 3 Sustainability	Treatment 4 Technology
Labgrown vs. none	-$0.34	$0.33	$0.86	$0.32
Plant-based using pea protein vs. none	$4.16	$2.30	$4.61	$3.14
Plant-based using animal-like proteins produced by yeast vs. none	$2.92	$2.73	$3.87	$3.34
Farm raised beef vs. none	$10.18	$10.89	$10.45	$11.35

Table 5. Relationship between Demographics and Market Shares

Variable	**Labgrown beef**	**Plant-based using pea protein**	**Plant-based using animal-like proteins produced by yeast**	**Farm-raised beef**
Intercept	0.133*[a]	0.242*	0.268*	0.357*
	(0.032)[b]	(0.047)	(0.04)	(0.072)
Vegetarian	0.043*	0.282*	0.171*	-0.495*
	(0.013)	(0.019)	(0.016)	(0.029)
Children under 12	0.002	-0.009	0.049*	-0.041
	(0.009)	(0.014)	(0.012)	(0.021)
College Degree	0.016*	0.026*	0.003	-0.045*
	(0.008)	(0.011)	(0.010)	(0.018)
Female	-0.024*	0.017	-0.030*	0.037*
	(0.008)	(0.011)	(0.010)	(0.017)
Income: $40k-$79k	-0.001	0.012	-0.0004	-0.011
	(0.008)	(0.012)	(0.010)	(0.018)
Income: $80k-$119k	-0.013	0.020	0.020	-0.027
	(0.011)	(0.016)	(0.014)	(0.025)
Income: >$120k	-0.018	0.031	0.015	-0.028
	(0.013)	(0.02)	(0.017)	(0.030)
Age	-0.003*	-0.005*	-0.005*	0.012*
	(0.001)	(0.002)	(0.002)	(0.003)
Age^2	0.00002	0.00003	0.00003	-0.00008*
	(0.00001)	(0.00002)	(0.00002)	(0.00003)
Household size	-0.002	-0.005	-0.014*	0.021*
	(0.003)	(0.005)	(0.004)	(0.008)
Northeast region	-0.006	-0.003	0.011	-0.002
	(0.011)	(0.016)	(0.014)	(0.024)
Midwest region	-0.002	-0.021	-0.013	0.036
	(0.010)	(0.015)	(0.013)	(0.024)
South region	-0.010	-0.005	0.007	0.008
	(0.009)	(0.014)	(0.012)	(0.021)
Treatment 2	-0.005	-0.010	-0.014	0.029
	(0.010)	(0.014)	(0.012)	(0.022)
Treatment 3	0.011	0.007	-0.004	-0.013
	(0.010)	(0.014)	(0.012)	(0.022)
Treatment 4	0.009	0.00001	0.007	-0.016
	(0.010)	(0.014)	(0.012)	(0.022)
R^2	0.02	0.15	0.13	0.21

[a]One asterisk represents statistical significance at the 0.01 level or lower.
[b]Numbers in parenthases are standard errors

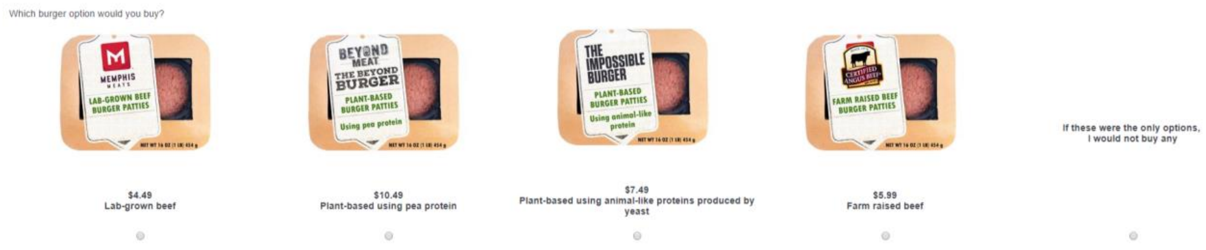
Table 6. Policy and Labeling Preferences

Policy	Support	Oppose
The USDA and FDA should prohibit the use of the word "beef" on the labels for labgrown meat	70.20%	29.80%
The USDA and FDA should prohibit the use of the word "beef" on the labels for plant-based meat using pea protein	76.10%	23.90%
The USDA and FDA should prohibit the use of the word "beef" on the labels for plant-based meat using animal-like proteins produced by yeast	75.80%	24.20%
10% tax on beef from cattle in an effort to reduce beef consumption for environmental and animal welfare objectives	31.20%	68.80%
Require that any product labeled as "beef" come from cattle that have been born, raised, and harvested in the traditional manner, rather than coming from alternative sources such as a synthetic product from plant, insects, or other non-animal components and any product grown in labs from animal cells	81.00%	19.00%

Note: The sample size yields a sampling error of about +/- 2.35%

Figure 1. Example of choice set with (A) and without (B) brand names

(A)



(B)

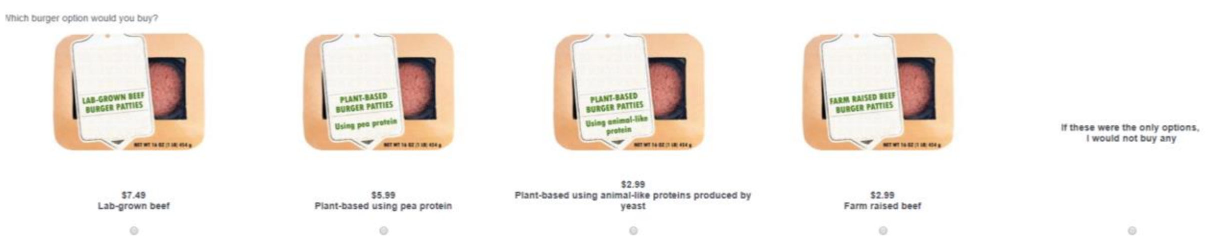


Figure 2. Sustainability (A) and technological (B) information

Figure 2.A

Conventional (farm raised) meat such as ground beef is produced from cows, bulls, steers, and heifers grown in a variety of environments across the country and abroad. Some groups have expressed concerns about environmental and animal welfare impacts of conventional beef production.

Three meat or protein alternatives have been suggested to be more environmentally friendly and better for animal welfare.

The table below compares some estimated reductions in environmental impacts of each of the three alternatives compared to conventional beef.

	Plant-based meat using pea protein	Plant-based meat using animal-like proteins produced by yeast	Lab-grown meat
Water	99% less	75% less	96% less
Land	93% less	95% less	99% less
Energy	46% less	93% less	45% less
Greenhouse gas emissions	90% less	87% less	96% less

Figure 2.B

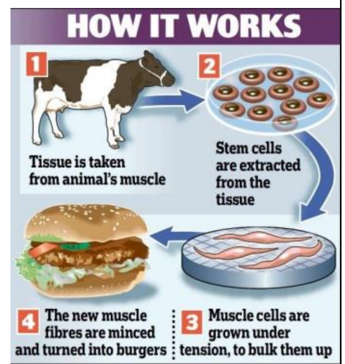
Plant-based meat using pea protein

The primary source of protein in this burger comes from peas. In addition, trace amounts of beet lend a beefy red color while coconut oil and potato starch ensure mouth-watering juiciness and chew. The result is an plant-based patty that mimics the taste of an animal meat burger patty.

Plant-based meat using animal-like proteins produced by yeast

The burger patty is made from plant-based heme, wheat protein, coconut oil, potato protein.

Heme is an iron-containing molecule that occurs naturally in every single plant and animal and is responsible for the characteristic of taste and aroma of meat. The plant-based heme is produced by a yeast, using fermentation. In order to have yeast producing the plant-based heme, the yeast is genetically engineered by adding the gene responsible to make heme in soy to the yeast. Since this heme is identical to the one found in animal meat, this plant-based burger patty mimics the taste of an animal meat burger.



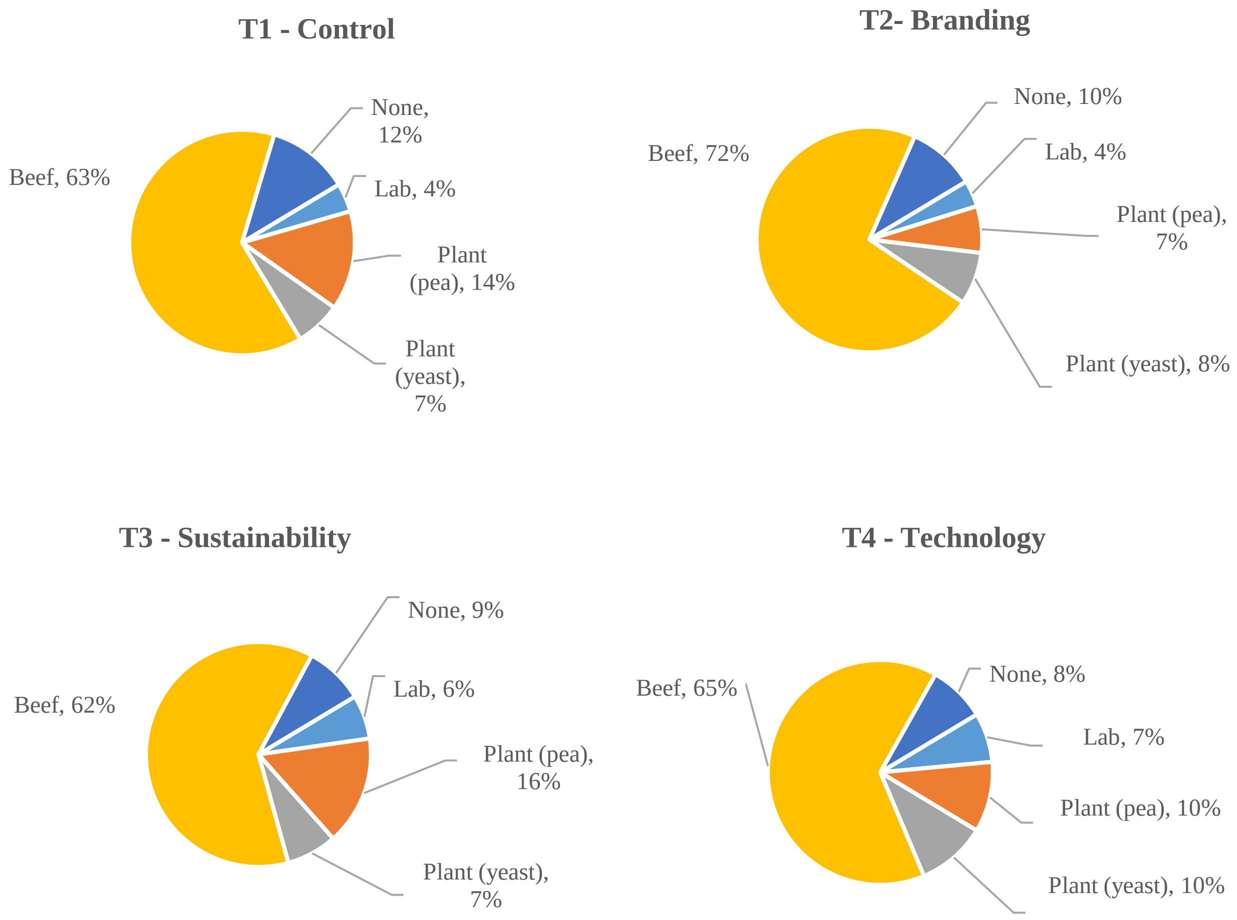
Labgrown beef

Labgrown meat is produced in the laboratory (see figure). Stem cells are obtained from the muscle tissue of cows. Scientists then feed and nurture the cells so they multiply to create muscle tissue, which is the main component of the meat we eat. It is biologically exactly the same as the meat tissue that comes from a cow. The result is a patty with a similar taste, texture and composition to traditional meat.

(Figure source: Daily Mail, 2019)

Figure 3. Predicted Market Shares by Treatment

A. Unconditional market shares



B. Conditional market shares (conditional on buying an option)

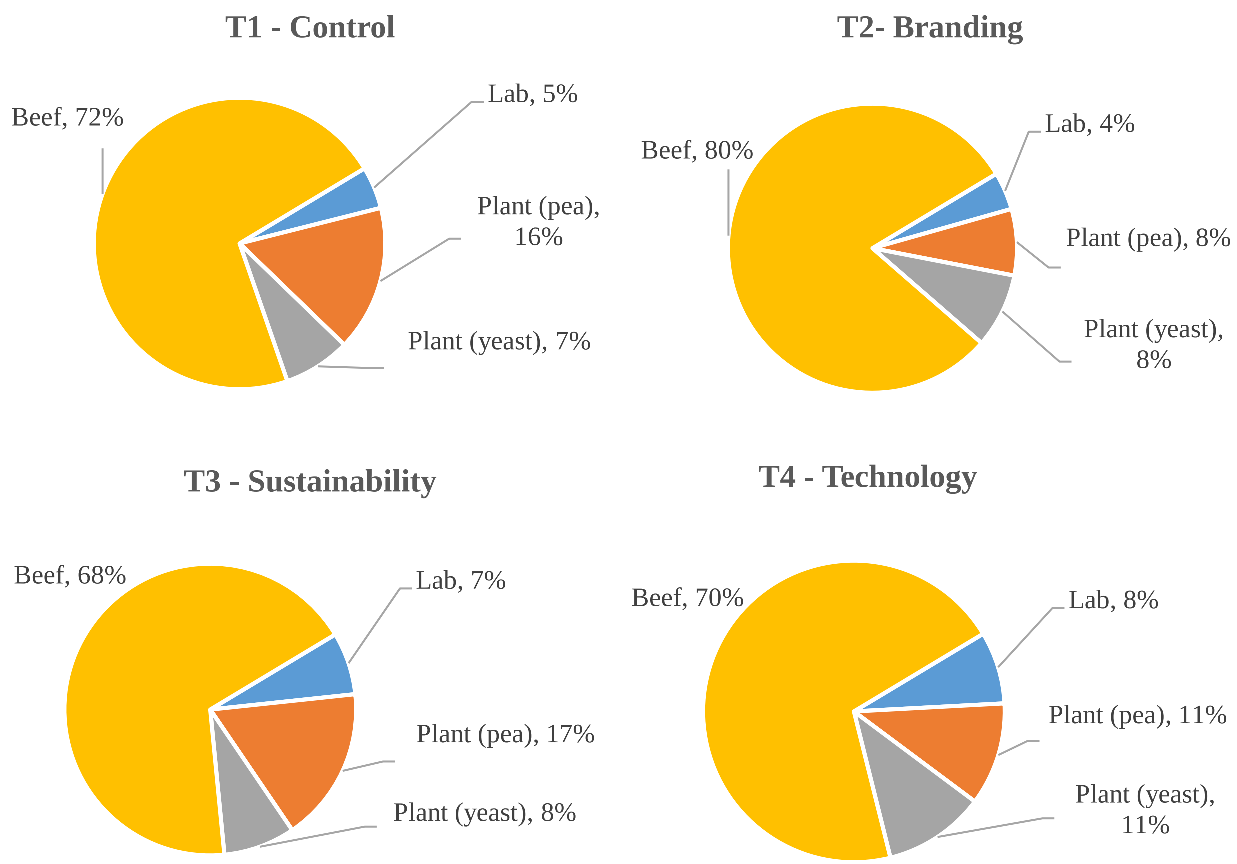
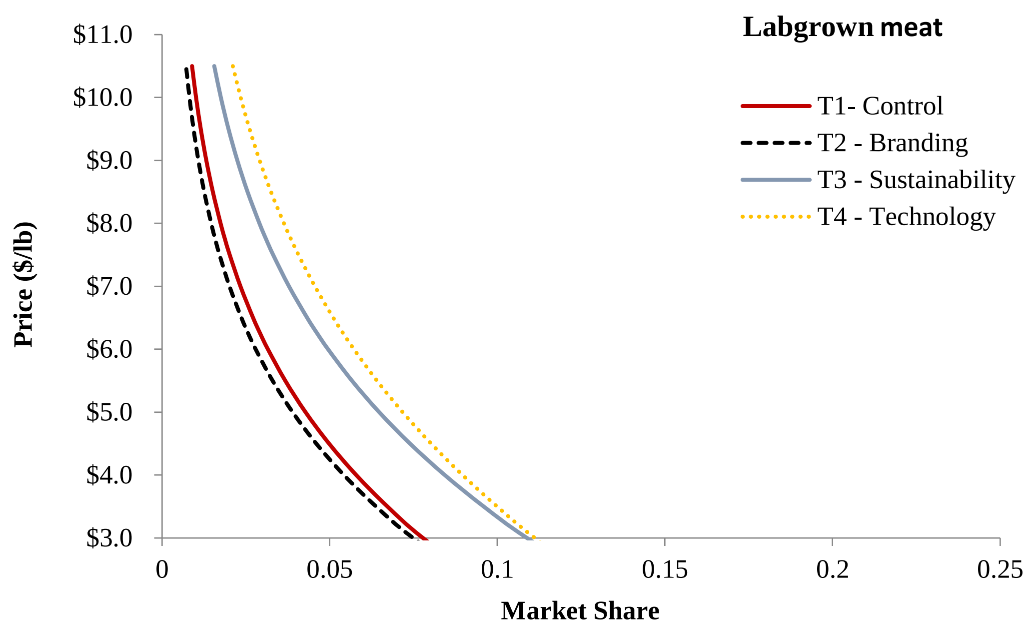
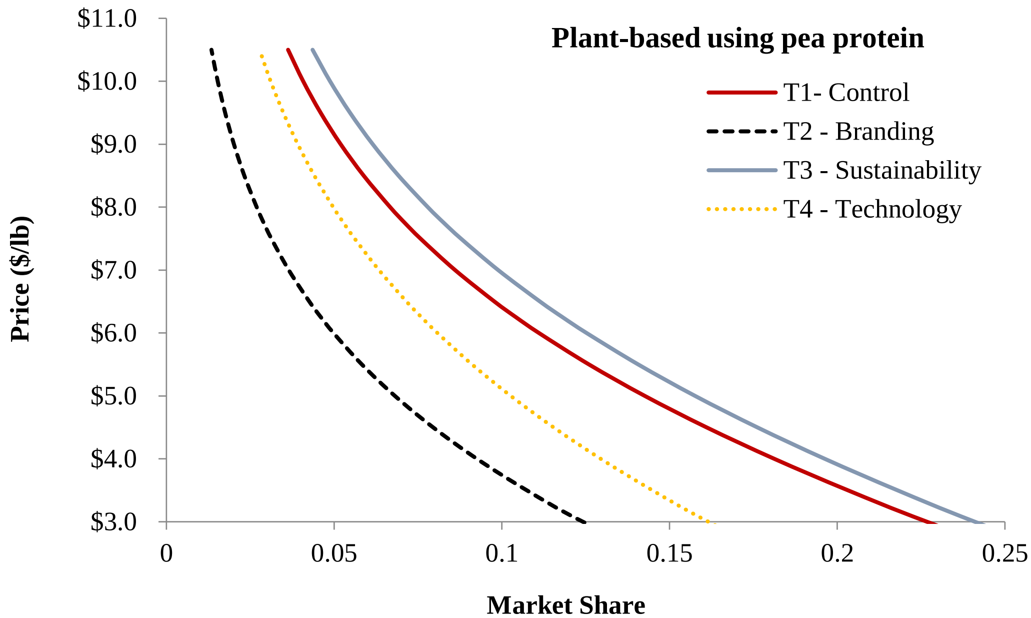


Figure 4. Implied demand curves for meat and meat-like burger patties: labgrown (A), Plant-based using pea protein (B), Plant-based using animal-like proteins produced by yeast (C), Farm-raised beef (D), by Treatment

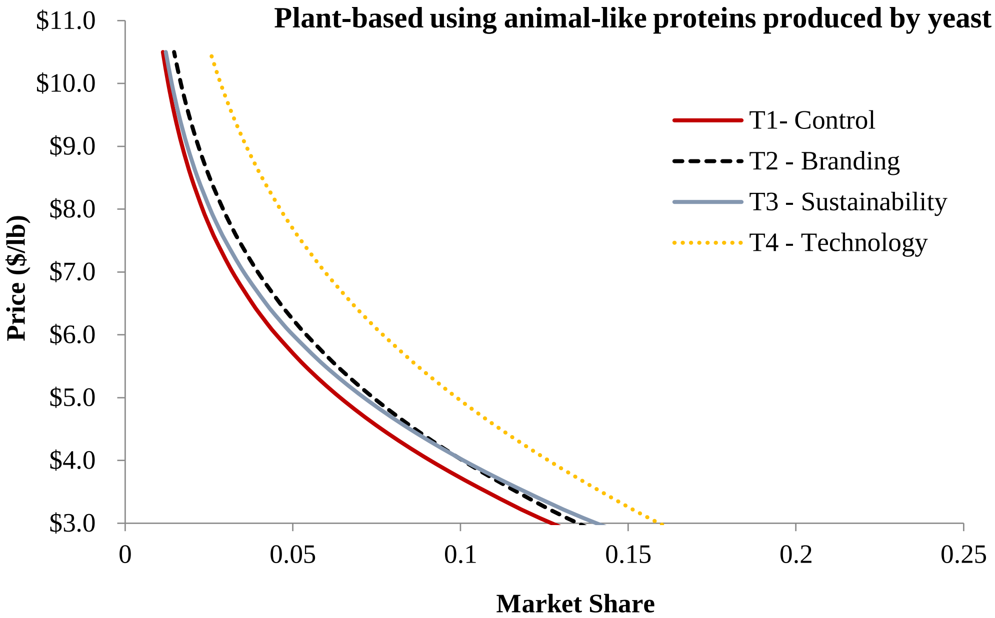
A)



B)



C)


Plant-based using animal-like proteins produced by yeast
T1- Control
T2 - Branding
T3 - Sustainability
T4 - Technology
Price ($/lb)
$11.0
$10.0
$9.0
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
0
0.05
0.1
0.15
0.2
0.25
Market Share

D)

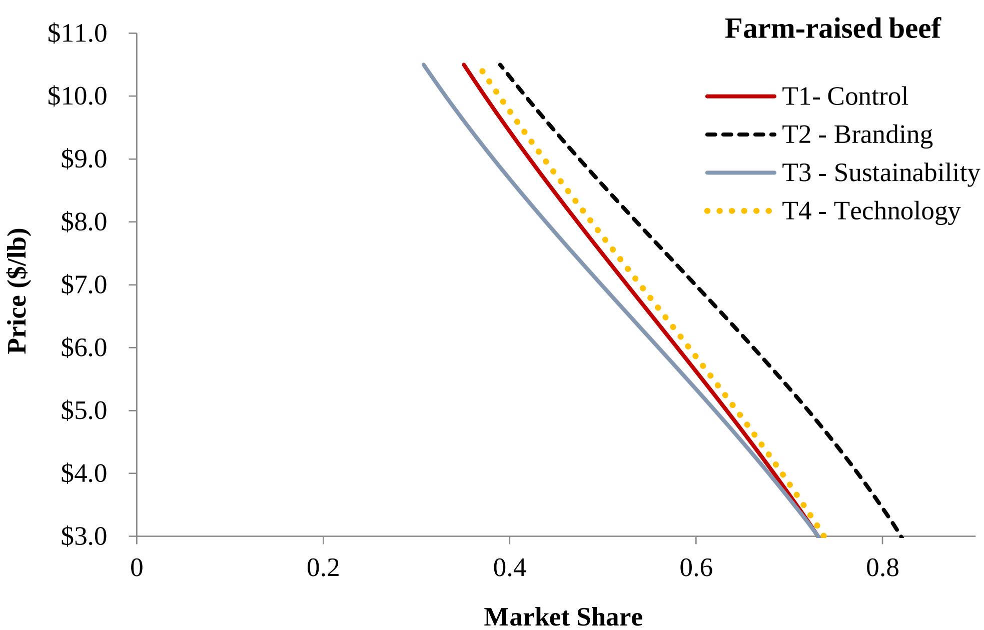
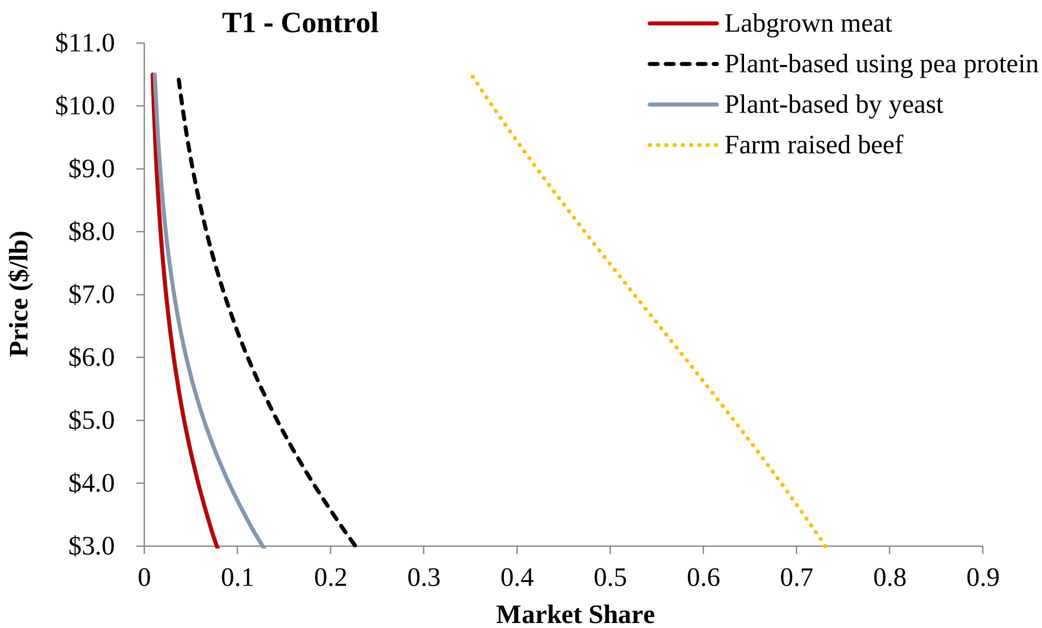
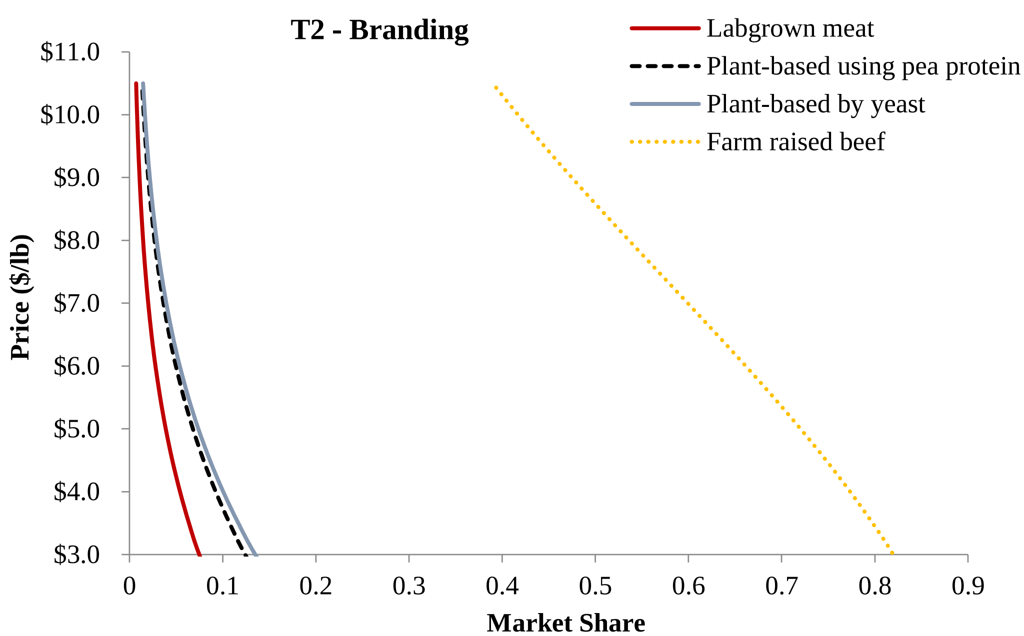

Farm-raised beef
T1- Control
T2 - Branding
T3 - Sustainability
T4 - Technology
Price ($/lb)
$11.0
$10.0
$9.0
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
0
0.2
0.4
0.6
0.8
Market Share

Figure 5. Implied demand curves for the meat and meat-like burger patties for each of the treatment (control (A), Branding (B), Sustainability (C) and Technology (D))

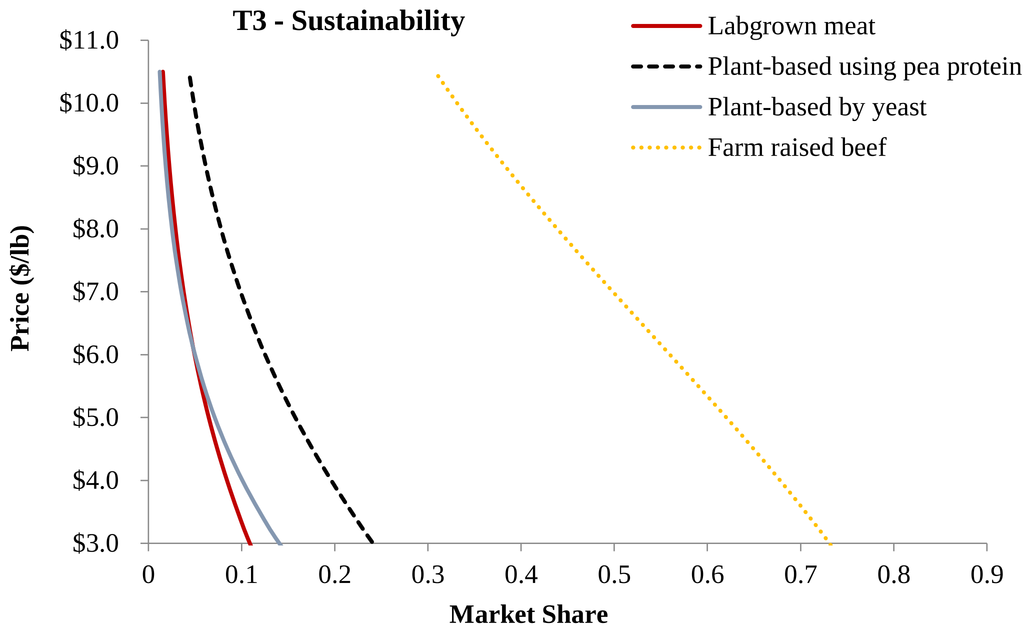
A)



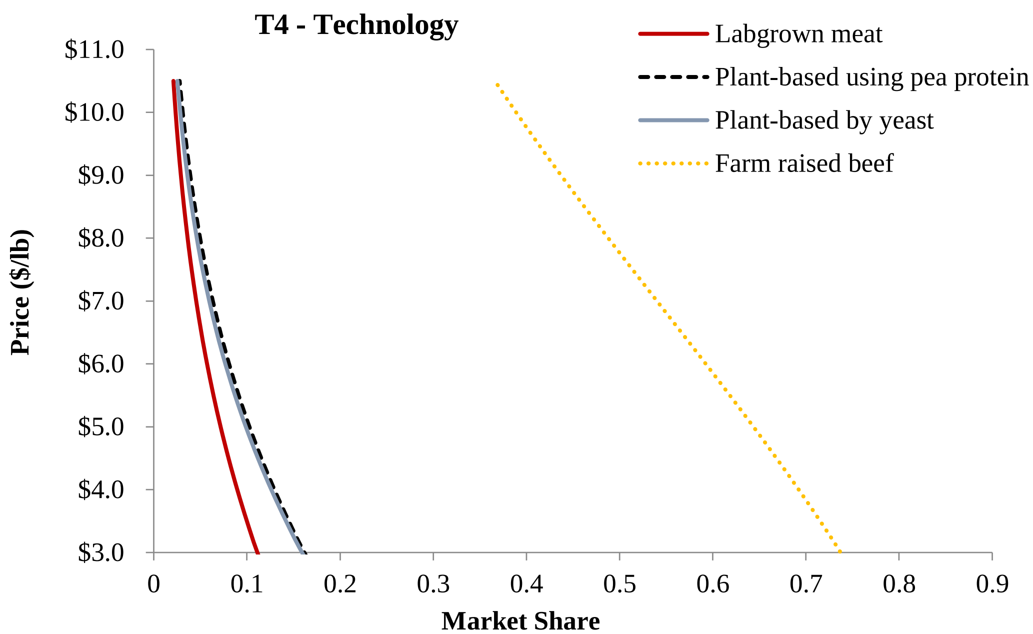
B)



C)


T3 - Sustainability
Labgrown meat
Plant-based using pea protein
Plant-based by yeast
Farm raised beef
Price ($/lb)
$11.0
$10.0
$9.0
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Market Share

D)


T4 - Technology
Labgrown meat
Plant-based using pea protein
Plant-based by yeast
Farm raised beef
Price ($/lb)
$11.0
$10.0
$9.0
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Market Share

Appendix

Table A1. Socio-demographic characteristics of the sample (%)

Characteristic	Sample (N=1830)	Population/Census
Region		
Northeast	18.6	17.5
Midwest	21.5	21.1
South	38.5	37.7
West	21.4	23.7
Gender		
Male	51.6	51.4
Female	46.8	48.6
Other	1.5	
Age		
18-24y	13.2	12.9
25-34y	18.3	17.6
34-44y	17.2	17.0
45-54y	15.09	18.4
55-64y	16.9	16.1
65-74y	16.0	10.0
75 and older	3.4	8.0
Education level		
Bachelor’s Degree or higher	35.1	33.4
Income		
Less than $20K	19.1	15.8
$20K–$39K	24.6	18.9
$40K–$59K	18.9	15.8
$60K–$79K	14.2	12.4
$80K–$99K	7.7	9.3
>$100K	15.6	27.7
Race and ethnicity[a]		
White	73.7	73.8
Hispanic	17.9	16.9
Black or African American	17.5	12.6

[a] Following the Census Bureau, Hispanic origin is asked separate from other race questions; as a result, the percentages sum to more than 100%.

Table A2. Count and percent of consumers choosing each alternative by treatment

Treatment		lab	plant	yeast	beef	none	Total	
							#choices	#people
1	count	221	475	363	2,395	695	4,149	461
	%	5.33	11.45	8.75	57.72	16.75	100	
2	count	193	410	362	2,527	774	4,266	474
	%	4.52	9.61	8.49	59.24	18.14	100	
3	count	274	517	406	2,319	561	4,077	453
	%	6.72	12.68	9.96	56.88	13.76	100	
4	count	251	454	406	2,271	596	3,978	442
	%	6.31	11.41	10.21	57.09	14.98	100	
Total		939	1,856	1,537	9,512	2,626	16,470	1830
		5.7	11.27	9.33	57.75	15.94	100	

Table A3. MNL estimates and resulting WTP

	Pooled	Treatment 1 Control	Treatment 2 Branding	Treatment 3 Sustainability	Treatment 4 Technology
MNL Estimates					
Lab vs none	0.079*	0.010	-0.270***	0.415***	0.162*
	(0.047)	(0.094)	(0.097)	(0.091)	(0.093)
Plant vs none	0.772***	0.790***	0.495***	1.062***	0.762***
	(0.041)	(0.082)	(0.083)	(0.082)	(0.084)
Yeast vs none	0.581***	0.519***	0.369***	0.815***	0.650***
	(0.042)	(0.085)	(0.085)	(0.085)	(0.085)
Beef vs none	2.500***	2.506***	2.421***	2.658***	2.447***
	(0.039)	(0.079)	(0.078)	(0.079)	(0.079)
Price	-0.178***	-0.186***	-0.180***	-0.181***	-0.163***
	(0.005)	(0.009)	(0.010)	(0.009)	(0.009)
WTP Estimates					
Lab vs none	$0.45	$0.05	-$1.50	$2.29	$0.99
Plant vs none	$4.35	$4.25	$2.75	$5.86	$4.67
Yeast vs none	$3.27	$2.79	$2.05	$4.49	$3.98
Beef vs none	$14.08	$13.47	$13.43	$14.65	$15.00
N choice	16470	4149	4266	4077	3978
N people	1830	461	474	453	442
Loglikelihood	-19660.6	-4911.2	-4904.1	-4955.7	-4846.1

Note: A likelihood ratio test of the null hypothesis that coefficients are equal across treatments yields a chi-square value of 87 with 15 degrees of freedom; the null is rejected at the $p<0.01$ level.