

1 **Title:** Consumers' perceptions of plant-based alternatives relative to the foods they directly
2 imitate

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15

16 **Abstract:** Plant-based alternatives (PBAs) that look and taste like animal-derived products have
17 developed rapidly in recent years in response to growing interest in sustainable alternatives.
18 However, PBAs face challenges meeting consumer expectations and mimicking the sensory
19 profile of animal-derived products. Thus, consumers generally view PBAs as a separate category
20 rather than animal-derived alternatives. The objective of this study was to characterize how
21 consumers perceive PBAs (meat and dairy) and compare them to the animal-derived products
22 they imitate. A total of 271 adults completed an online questionnaire, where they viewed food
23 images (PBA, animal-derived and control products), reported expected tastiness, purchase
24 intention, and endorsed descriptors using check-all-that-apply. Person-related factors influencing
25 PBA perception were also assessed. PBAs were rated significantly lower in expected tastiness
26 and purchase intention. Correspondence analysis confirmed that PBAs were perceived as distinct
27 from their AD counterparts, and that PBAs were associated with the terms unnatural, eco-
28 friendly, modern, adventurous, expensive, and bland, while animal-derived products largely
29 separated by perceived healthiness. A penalty-lift analysis revealed that processed, unnatural,
30 and bland were the top drivers of low PBA purchase intention. Furthermore, participants' trust in
31 the food industry (positively) and food technology neophobia (negatively) predicted PBA
32 acceptance. Together, this study confirms perceived taste as a PBA adoption barrier while also
33 identifying unnaturalness and fear of food technology as important challenges. In addition to
34 pursuing taste improvements, PBA developers should consider strategies to address the unnatural
35 and processed perception of these products.

36

37 **Keywords:** sustainability, food technology neophobia, unnatural, processing, taste

38 **1. Introduction**

39 Interest in plant-based alternatives (PBAs) has grown due to their potential benefits as
40 healthier, animal-friendly, and more environmentally sustainable options (Ismail et al., 2020;
41 Keoleian & Heller, 2018; Thorbecke & Dettling, 2019). PBAs are made from plant ingredients
42 that are marketed as alternatives and imitate the sensory properties of animal derived foods.
43 PBAs are expected to have sustainability advantages compared to livestock, resulting in lower
44 greenhouse gas emissions, less land use, and increased water and energy efficiency (Carey et al.,
45 2023; Djekic, 2015; Ismail et al., 2020; Rööös et al., 2013). Due to growing interest in reducing
46 meat consumption (Neff et al., 2018), next-generation products that mimic conventional products
47 have been developed to meet anticipated consumer demand. The motivation behind the
48 development of PBAs is to provide options that taste like conventional animal products, with the
49 assumption that greater similarity to animal products will improve acceptance (Swann & Kelly,
50 2023). Greater adoption of PBAs is intended to support the shift away from animal consumption
51 and aid in achieving a more sustainable diet (van der Weele et al., 2019). For the purpose of the
52 present study, PBA refers to products designed to mimic conventional animal products (e.g.,
53 Beyond Meat and Impossible Burger), as opposed to other plant-based protein products that do
54 not attempt to mimic animal-derived products, such as tofu or black bean burgers.

55 Despite the purported benefits of PBAs, consumers adoption has been slow (International
56 Food Information Council, 2023). Furthermore, PBAs have largely fallen short of the goal to
57 shift consumption away from animal-derived products, as global plant-based meat and seafood
58 sales make up less than 1% of the total meat category (Battle et al., 2023), raising the question of
59 whether these products are successfully guiding consumers toward a healthier and more

60 sustainable diet. Investigations into consumers' perception of PBAs have identified several
61 product-related barriers, such as taste and cost (International Food Information Council, 2023;
62 Jahn et al., 2021; J. Li et al., 2023). Because PBAs are marketed as alternatives to their animal-
63 derived counterparts, the disconnect between sensory expectations and actual experiences can
64 leave consumers disappointed (Battle et al., 2023; Fiorentini et al., 2020; Giacalone et al., 2022).
65 For example, appearance, taste, and mouthfeel of PBA products are not comparable to their
66 animal-based counterparts (Appiani et al., 2023; Michel et al., 2021; Moss et al., 2023; Neville et
67 al., 2017). Numerous sorting studies have demonstrated that consumers generally perceive dairy
68 and especially meat alternatives as a category distinct from the foods they imitate, rather than as
69 direct alternatives to animal-derived products (Chollet et al., 2022; Etter et al., 2024; Hoek et al.,
70 2011; van der Meer et al., 2023). Considering that PBAs are perceived as distinct from their
71 animal-derived counterparts, additional research on consumer perception of this category can
72 help promote their acceptance. Categories (e.g., PBAs) help consumers interpret attributes about
73 a set of related products, which in turn helps them process information and make judgements
74 about new products within that category; thus, category perceptions influence purchase intention
75 by helping consumers make inferences about new products (Loken et al., 2008). For example,
76 Cardello et al. (2022) found that conceptual, emotional, and situational-use associations with
77 plant-based categories significantly influenced consumers' willingness-to-consume. Therefore,
78 describing how consumers conceptualize the PBA category is crucial to supporting purchase
79 intention of current and future products.

80 Previous attempts to reveal how consumers perceive PBA relative to animal-derived
81 products have largely focused either on meat alternatives broadly (Cornelissen & Piqueras-

82 Fiszman, 2023; de Oliveira Padilha et al., 2022; Knaapila et al., 2022; Michel et al., 2021;
83 Possidónio et al., 2021; Spendrup & Hovmalm, 2022; Vural et al., 2023) or sorting tasks (Chollet
84 et al., 2022; Etter et al., 2024; Hoek et al., 2011; van der Meer et al., 2023). Few have directly
85 compared various types of animal-derived products with the PBA that seek to mimic those
86 products. Furthermore, existing studies directly comparing PBA and animal-derived products
87 have reached different conclusions: although PBA are generally viewed as healthier and more
88 eco-friendly than meat, the opposite may be true for some products or among some populations
89 (Cornelissen & Piqueras-Fiszman, 2023; de Oliveira Padilha et al., 2022; Hartmann et al., 2022;
90 Michel et al., 2021; Spendrup & Hovmalm, 2022; Vural et al., 2023). Therefore, additional
91 studies are merited to understand how PBA are perceived relative to the animal-derived products
92 they mimic. Because the acceptance of PBAs is product dependent, it is most productive to
93 examine acceptance based on perception of individual products, rather than ask consumers to
94 describe the abstract concept of plant-based foods (Cardello et al., 2022; Hartmann & Siegrist,
95 2017).

96 In addition to perceived taste, health, and sustainability, PBAs are also viewed as less
97 natural than animal-derived products (Hartmann et al., 2022). Several studies have documented
98 that perceived unnaturalness or processing may lower acceptance of PBAs (Aschemann-Witzel
99 et al., 2021; Hwang et al., 2020; Knaapila et al., 2022; Varela et al., 2022). Furthermore,
100 purchasers of PBA reported that processing, following taste and price, is the top barrier to repeat
101 purchase (International Food Information Council, 2023). Together, these data suggest that
102 perceived unnaturalness or processing may remain a barrier to adoption even if sensory
103 acceptance and price parity were achieved. However, while these previous studies have

104 identified perceived processing or unnaturalness as potential barriers, few have made a
105 distinction between these two terms. Although the concepts of processing and unnaturalness are
106 related (Evans et al., 2010), differentiating how each applies to PBAs separately could reveal
107 more nuanced strategies to increase consumers acceptance of PBAs. Thus, further investigation
108 is merited to understand the barrier of perceived product unnaturalness and processing relative to
109 other well-studied barriers.

110 Person-related factors are also associated with perceptions, attitudes, and consumption of
111 PBAs. For example, concern for animal welfare, health, and the environment are associated with
112 interest and motivation to consume PBA (Cornelissen & Piqueras-Fiszman, 2023; Knaapila et
113 al., 2022; Onwezen et al., 2021; Possidónio et al., 2021). There is conflicting evidence on
114 whether food neophobia (the fear of trying new foods) is associated with acceptance of PBA
115 (Faria & Kang, 2022; Onwezen et al., 2021). Newer studies suggest that rather than the fear of
116 trying new food, the fear of food technology, or food technology neophobia (FTN) may be more
117 important for understanding the rejection of plant-based foods (Jiang et al., 2024) and other
118 foods (Wendt & Weinrich, 2023). Recent studies suggest that trust in the food system is also
119 associated with acceptance of PBA (Begho et al., 2023; Faber et al., 2024). Demographic
120 variables have also been associated with PBA acceptance - in general, regular consumers of PBA
121 tend to be younger, female, and educated (Cornelissen & Piqueras-Fiszman, 2023). Therefore,
122 the inclusion of person-related factors is important when studying PBA acceptance.

123 Considering the growing concern among consumers regarding the fear of food processing
124 and mistrust for food products, including PBA, it is important to investigate how these person-
125 related factors may play a role in the attitudes and perceptions of PBA. Further, because many

126 consumers view PBA as a single category (Cardello et al., 2022) and consumers use category
127 concepts to make judgements about new and existing product (Loken et al., 2008), it is important
128 to identify how consumers perceive the category. Therefore, the primary objectives of the current
129 study are to 1) assess how consumers describe PBAs relative to animal-derived foods, and 2)
130 identify person-related factors that predict PBA acceptance. We hypothesize that factors such as
131 perceived processing and unnaturalness are significant barriers to PBA acceptance, in addition to
132 the well-studied factors of taste and cost.

133 2. Methods

134 2.1. Participants

135 A sample of 276 adults (18 years or older) residing in the United States were recruited via
136 an online survey platform (Prolific). Participants were drawn from the entire Prolific panel. All
137 data were collected using Qualtrics survey software. No other inclusion or exclusion criteria
138 were used. All procedures were approved by the corresponding author's institutional review
139 board. Five participants failed an attention check question, leaving a final sample of 271
140 participants (mean age = 40.8; 147 female and 4 non-binary; additional characteristics are
141 reported in Table 1). The median age of the sample (38.5) is comparable to the median age of the
142 US population according to census data (38.8). Relative to the US census, our sample leaned
143 slightly more female (54.2% vs 50.5%), more White/Caucasian (81.3% vs 72.9%), and less
144 Hispanic/Latino (10% vs. 18.8%), and included fewer participants older than 65 (4.9% vs
145 16.9%), respectively (*Census Bureau Data*, n.d.). Most participants consumed animal products
146 regularly, with 83% reporting at least weekly consumption of beef/pork/poultry and 88%

147 reporting at least weekly consumption of dairy products. A small percentage reported avoiding
 148 animal products, with 6% and 4% eating beef/pork/poultry and dairy only once per year or less,
 149 respectively. Approximately half of the sample reported rarely (once a year or less) consuming
 150 plant-based meat products, and 40% reported rarely consuming plant-based dairy.
 151 Approximately 11% and 24% of the sample consumed plant-based meat and plant-based dairy at
 152 least weekly, respectively. Each participant provided informed consent and received monetary
 153 compensation for their survey completion.

154 **Table 1:** Participant characteristics.

Demographic (n = 271)	Number (percentage)
Mean age	40.8 (std. dev = 12.9)
Gender	
Male	119 (44)
Female	147 (54)
Other	4 (2)
Prefer not to disclose	1 (< 1)
Education	
Less than high school degree	4 (2)
High school	32 (12)
Some college	62 (23)
Associate degree in college (2-year)	28 (10)
Bachelor's degree in college (4-year)	100 (37)
Master's degree	37 (14)
Doctoral degree	3 (1)
Professional degree (JD, MD)	5 (2)
Income	
\$0 - \$24,999	32 (12)
\$25,000 - \$49,999	74 (27)
\$50,000 - \$74,999	54 (20)
\$75,000 - \$99,999	41 (15)
\$100,000 - \$149,000	39 (14)
\$150,000 or more	31 (11)

155

156 *2.2. Survey*

157 Participants first encountered a general introduction: “This survey asks what you think
158 about certain foods. You will be shown several foods (name, picture, and ingredients) and asked
159 to rate how much you think you would like that food and how likely you are to buy it. Please
160 imagine a situation where you would be presented with this food. Please answer the question
161 based on the name of the food.” Participants were shown pictures of 22 different foods
162 (Supplemental Table 1), one at a time, along with the ingredients found in that food in a random
163 order. The foods included eight pairs of PBA foods and the animal-derived versions of those
164 foods (cheese, milk, yogurt, chicken, chicken nuggets, burger, sausage, and meatballs). These
165 foods were chosen to represent commonly consumed foods in the US from different types of
166 animal derived protein sources (dairy, beef, chicken, and pork) and various levels of processing.
167 To control differences in appearance and isolate the effect of product name and ingredients, the
168 same image was used for both the PBA and animal-derived version of the food (chicken as the
169 only exception due to market availability of a plant-based chicken breast; hamburger and plant-
170 based burger images were nearly identical). To provide context for other protein foods, beef
171 steak, refried beans, tofu, black beans, and a black bean/veggie burger were also included.
172 Cooked rice was included as a non-protein reference. These foods represent foods that are not
173 marketed as imitations of animal food products. The inclusion of these neutral foods serves as a
174 reference, helping to validate the approach as we expect these products to be perceived as
175 distinct from animal products. Participants rated each food for purchase likelihood and expected
176 taste liking. Purchase likelihood and expected taste liking were measured using a 7-point Likert
177 scale (purchase likelihood: 1=very low, 7=very high; expected taste liking: 1=would not like at
178 all, 7=would like extremely). Participants were then presented with a check-all-that-apply

179 (CATA) question containing 18 descriptors in a random order for each food they were shown
180 (Tasty, Convenient, Processed, Modern, Healthy, Eco-friendly, Unnatural, Good source of
181 protein, Expensive, Familiar, Adventurous, Boring, Natural, Traditional, Bland, Cheap,
182 Wholesome, Unhealthy) and asked to check all words that describe the food according to their
183 perception. The CATA terms were chosen and adapted from a previous study of PBA foods
184 (Jaeger et al., 2023). The foods were presented in commonly consumed forms and presented in
185 portions that may be consumed in a single sitting. With the exception of three products, foods
186 were prepared and photographed by the researchers. Milk, yogurt, and cheese images were
187 obtained from the food-pics image database (Blechert et al., 2014).

188 After evaluating the food images, participants answered questions related to their
189 intake/consumption frequency, health values (Haws et al., 2014), green consumer values (Haws
190 et al., 2014), attitude toward meat consumption (Moussaoui et al., 2023), food technology
191 neophobia (FTN) (Cox & Evans, 2008; Wendt & Weinrich, 2023), and trust in the food industry
192 (Siegrist & Hartmann, 2020b). The survey also collected participants' demographics (age,
193 gender, education, income, and race/ethnicity).

194

195 *2.3. Data analysis*

196 Because the majority of consumers show little differentiation in their willingness-to-
197 consume various types of PBAs (Cardello et al., 2022) and to describe the perceptions of the
198 PBA category generally, we categorized foods as either PBA and or animal-derived (products
199 imitated by PBA) for analysis. Differences in liking and purchase intention between animal-

200 derived and PBA foods were determined using a one-way repeated measures MANOVA.
201 Wilcoxon signed rank tests were carried out for each descriptor to determine if there was a
202 difference in the use of the term for PBA vs. animal-derived foods. To minimize the likelihood
203 of Type I error, we used a Bonferroni correction to adjust the family-wise error rate of $\alpha = 0.05$
204 to a pairwise comparison α of 0.003 (i.e., family-wise α of 0.05 divided by 18 comparisons).

205 CATA data was used to generate a contingency table using the 22 foods as rows and the
206 18 descriptors as columns. A correspondence analysis was then performed with this data using
207 chi-squared distances (R studio, version 4.3.1, FactoMineR package,) to obtain a bi-dimensional
208 representation of the foods and descriptors. Correspondence analysis is a commonly used
209 technique to visualize variation of contingency table data (Meyners et al., 2013). Variation is
210 represented by two dimensions. The contribution of each term to the construction of each
211 dimension can be quantified to aid in the interpretation of that dimension (i.e., what the
212 coordinate values suggest about the term). Additionally, how well each term is represented by
213 the dimension can also be quantified using the cosine squared (\cos^2) value (i.e., how much of the
214 variation of that term/product is explained by the given dimension). The CATA data was also
215 used to conduct a penalty-lift analysis for both PBA and animal-derived foods (Meyners et al.,
216 2013). To focus on descriptors that are more broadly used to describe the products, only terms
217 with at least 20% endorsement frequency were included in the penalty lift. An independent
218 samples t-test was used to determine differences between endorsers and non-endorsers of each
219 term. To explore how PBA product perceptions predict acceptance, we conducted a Spearman's
220 rank correlation between PBA descriptor endorsement frequency across the eight products and
221 PBA purchase intention.

222 To systematically identify the most salient person-related variables that predicted PBA
223 and animal-derived product purchase intention, we conducted a stepwise multiple linear
224 regression (Wang et al., 2016). Prior to the analysis, we checked the assumption of collinearity,
225 and it indicated that multicollinearity was not a concern as the Variance Inflation Factor (VIF)
226 values were below 2.5 (Senaviratna & A. Cooray, 2019). Purchase intention was considered the
227 dependent variable, and the person-related factors (i.e., consumption frequency, health values,
228 green values, meat consumption attitude, food technology neophobia, trust, age, gender,
229 education and income) were the predicting (independent) variables.

230 Unless otherwise noted, all analyses were done using SPSS version 29.01 (IBM
231 Corporation, NY, USA).

232

233 3. Results:

234 3.1 Descriptive data on term endorsement

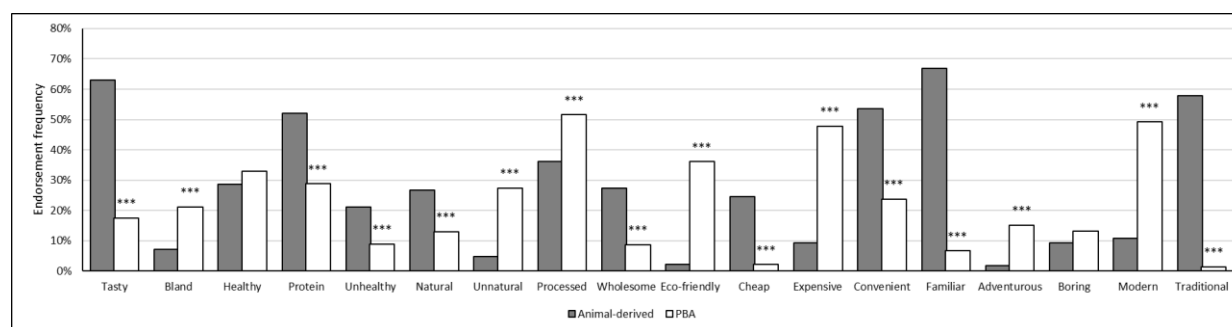
235 We first report how participants rated the average expected tastiness of the eight animal-
236 derived foods and the plant-based alternatives (PBA) designed to mimic those foods (Table 2).
237 Animal-derived and PBA foods were perceived as significantly different, based on the
238 MANOVA test ($F = 222.03, p < 0.001$). Participants rated the animal derived foods as
239 significantly tastier than the PBA version and were significantly more likely to purchase the
240 animal-derived version of the food (Table 2).

241 **Table 2: Differences in expected tastiness and purchase intention between images of plant-based alternatives**
242 **(PBA) and the animal-derived (AD) foods the mimic.** Mean (standard deviation) values from all participants are
243 shown. Ratings were collected using a 7-point scale. The F statistic and p -value from univariate tests following a
244 repeated measures MANOVA is shown. Degrees of freedom (df) of the model = 1; df of the error term = 270.

Outcome	n	AD	PBA	df	F	p-value
Expected tastiness	271	5.6 (0.96)	3.4 (1.51)	1	407.15	<0.001
Purchase intention	271	5.2 (1.29)	3.2 (1.60)	1	255.91	<0.001

245

246 To examine how participants viewed PBA vs animal-derived foods, we also report
 247 CATA descriptor frequency (Figure 1). Endorsement frequency of the reference foods (black
 248 beans, tofu, refried beans, rice, veggie burger, beef steak) are provided in Supplemental table 2.



249

250 **Fig 1: Endorsement frequency of descriptors for PBA vs animal-derived foods.** Animal-derived foods include
 251 the average endorsement frequency of cheese, yogurt, milk, sausage, chicken, chicken nuggets, burger, and
 252 meatballs. PBA includes the plant-based versions of those same eight products. The results of the Wilcoxon signed
 253 ranked test are shown as *** = $p < 0.001$; ** $p < 0.003$ (the Bonferroni-corrected α for single comparisons); * $p = < 0.05$.
 254

255

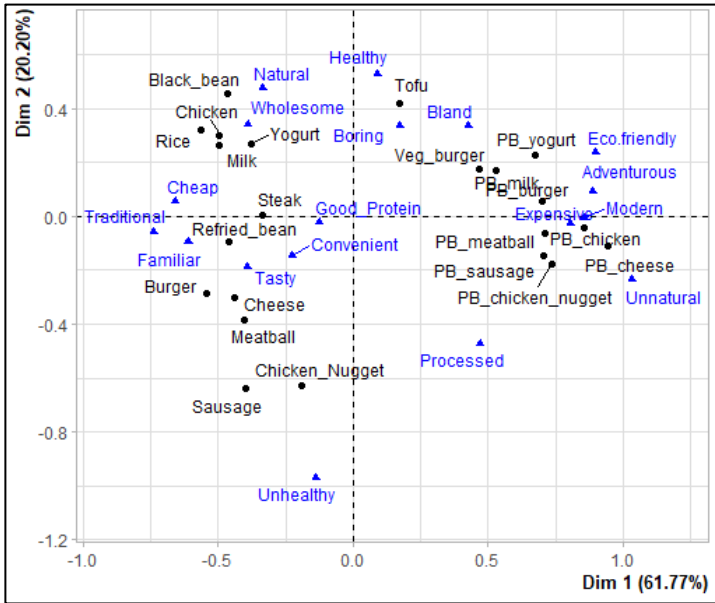
256 Compared to animal-derived products, PBA foods were seen as “eco-friendly” ($Z =$
 257 11.34), “adventurous” ($Z = 8.10$), “modern” ($Z = 11.23$), “bland” ($Z = 7.96$), “expensive” ($Z =$
 258 12.32), “unnatural” ($Z = 10.22$), and “processed” ($Z = 7.04$). Conversely, descriptors “unhealthy”
 259 ($Z = -7.88$), “cheap” ($Z = -11.43$), “tasty” ($Z = -12.98$), “good source of protein” ($Z = -10.2$),
 260 “natural” ($Z = -7.32$), “wholesome” ($Z = -10.08$), “convenient” ($Z = -11.51$), “familiar” ($Z = -$
 261 13.84), and “traditional” ($Z = -13.94$) were selected less frequently. There were no differences in
 262 the endorsement frequency of “healthy” ($Z = 1.87$) or “boring” ($Z = 1.93$) (Figure 1).

263 3.2 Correspondence analysis

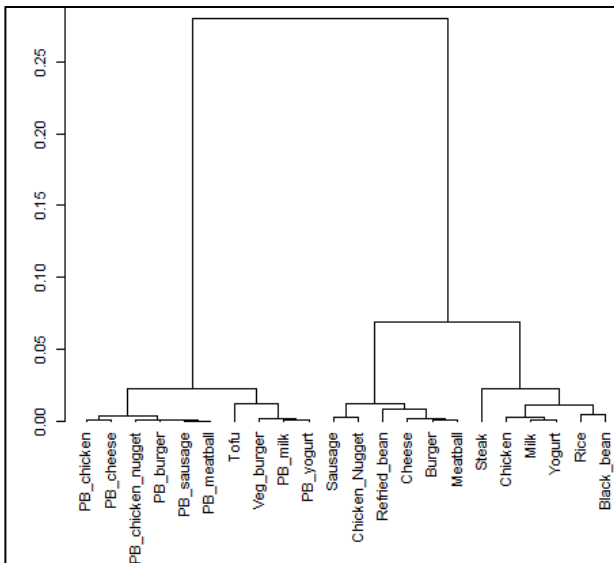
264 Next, we conducted a correspondence analysis on the contingency table of individual
265 food images and endorsed CATA terms to visualize how PBA foods are perceived relative to the
266 animal-derived food they mimic. We report both the term contribution (the meaning of the
267 dimension) and the \cos^2 (how well that dimension explains the term; higher \cos^2 indicates that
268 the term is well-represented) to interpret our data. The first two dimensions represent
269 approximately 82% of the variance of the correspondence analysis, thus we focus our
270 interpretation on these first two dimensions. The first dimension was constructed primarily by
271 PBA products and the terms associated with them (eco-friendly, modern, expensive, and
272 unnatural vs. familiar and traditional), and explains 62% of the total variance of the
273 correspondence analysis. Furthermore, PBA foods were highly represented by the first
274 dimension ($\cos^2 > 0.9$ for all PBAs, apart from PB milk and PB yogurt, each with a $\cos^2 > 0.7$),
275 indicating that the first dimension explains the large majority of variance among the tested
276 products (Supplemental Table 3). A hierarchical clustering analysis dendrogram further confirms
277 the clear separation of PBA from their animal-derived counterparts, and shows that PB milk and
278 PB yogurt clustered less strongly with the other PBAs (Figure 2B).

279

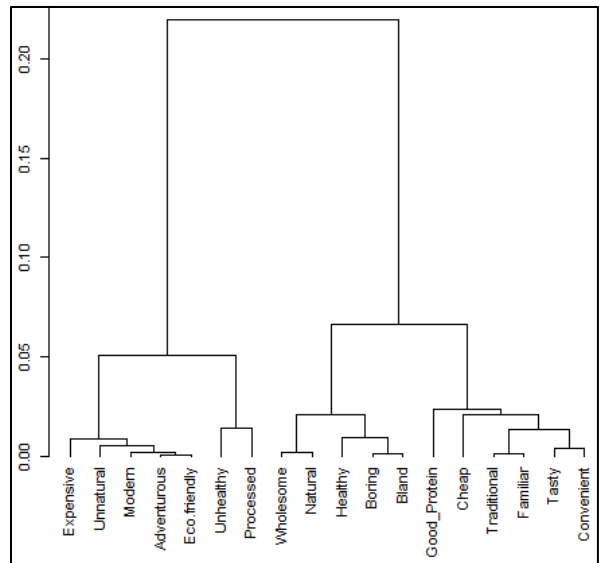
A



B



C



280 **Figure 2: Correspondence analysis (A) and hierarchical cluster analysis dendrograms of products (B) and**
 281 **descriptors (C) from the CATA contingency table.** (A) Blue labels with a triangle represent CATA descriptors.
 282 Black labels with circles refer to food products (images) presented. Labels with “PB_” refers to “Plant-based”.

283

284 The second dimension explains another 20% of the variance and was heavily influenced
285 by “healthy” and “unhealthy” descriptors. The animal-derived products separated to some degree
286 based on their perceived healthiness (with chicken nuggets and sausage alone contributing 40%
287 of the dimension construction, due to their strong association with “unhealthy”); meanwhile
288 relatively little of the PBA food variance was represented by the second dimension ($\cos^2 < 0.1$
289 for each PBA); this observation aligns with the frequency data showing that PBA are not
290 strongly seen as healthy or unhealthy.

291 The term “processed” loaded almost equally on both dimensions (\cos^2 of 0.46 on both
292 dimensions), suggesting that consumers associate the term with both unhealthiness and
293 unnaturalness. Furthermore, the hierarchal clustering dendrogram shows “unhealthy” and
294 “processed” clustering together early. Meanwhile, “unnatural” loaded primarily on the first
295 dimension ($\cos^2 0.87$), suggesting that the term may be viewed as distinct from health.

296 We next examine the reference foods that loaded near PBA foods to describe potential
297 associations between these products. Veggie burger clustered near plant-based milk and yogurt
298 shortly before clustering with tofu and then the remaining PBAs. Tofu clustered near “healthy”,
299 “bland”, and “boring”. While tofu was represented modestly well on both the first and second
300 dimensions ($\cos^2 0.48$ and 0.47 , respectively), the veggie burger was represented more strongly
301 on the first dimension (PBA vs not PBA) than the second (healthy vs unhealthy) ($\cos^2 0.62$ and
302 0.08 , respectively). The remaining reference foods clustered apart from PBAs and separated
303 mainly on the second dimension (primarily driven by “healthy” and “natural” vs. “processed”
304 and “unhealthy”).

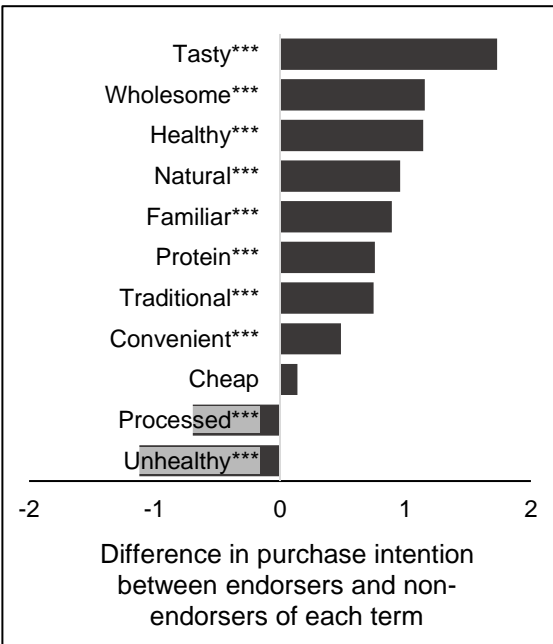
305

306 *3.3 Penalty lift analysis*

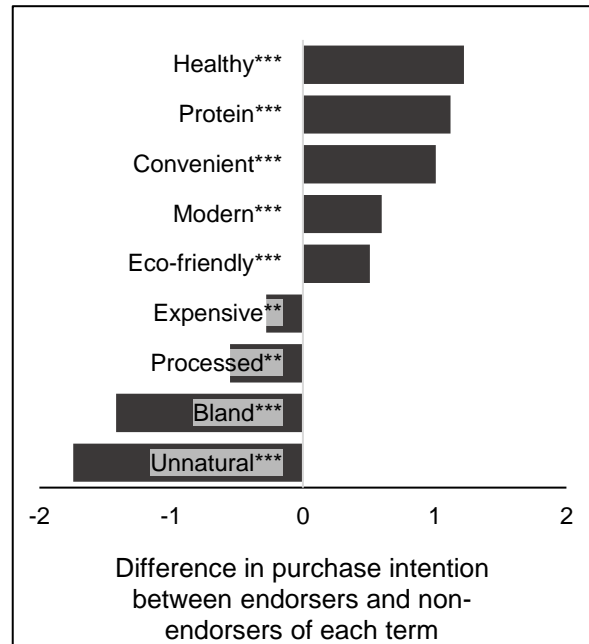
307 To identify the relative impact of the positive and negative descriptors on PBA purchase
308 intention, we conducted a penalty lift analysis. To focus on descriptors that are more commonly
309 associated with the products, only terms endorsed by at least 20% of participants are displayed
310 (see Figure 1). As a comparison, the penalty lift of animal-derived products was conducted to
311 determine how the same participants used the terms to describe different food classifications.
312 The penalty lift analysis is reported in Figure 3.

313

Animal-derived



PBA



315 **Figure 3: Penalty lift analysis of PBA (right) and the animal-derived (left) foods they mimic, according to**
 316 **PBA purchase intention.** Only terms endorsed >20% of the time are included. Based on independent samples t-test,
 317 * $p < 0.05$; ** $p < 0.003$ (the Bonferroni-corrected α for single comparisons); *** $p < 0.001$.

318

319 Endorsement of the terms “healthy”, “good source of protein”, and “convenient” lifted
 320 purchase intention in both product sets ($t = -13.86, -12.12, -10.16$ for PBA; $t = -14.04, -8.785, -$
 321 5.59 , respectively). Animal-derived food purchase intention was also lifted significantly by
 322 “tasty”, “wholesome”, “natural”, “familiar”, and “tradition” ($t = -19.26, -14.32, -10.89, -9.46, -$
 323 8.45 , respectively); meanwhile, “modern” and “eco-friendly” significantly and uniquely lifted
 324 PBA purchase intention ($t = -7.00, -5.67$, respectively). The term “processed” penalized both sets
 325 ($t = 7.47$ for animal-derived; $t = 6.45$ for PBA). The term “unhealthy” ($t = 9.68$) was associated

326 with the largest animal-derived penalty, while “bland” and “unnatural” ($t = 17.41, 22.77,$
 327 respectively) had the largest penalty for PBA foods.

328 *3.4 Associations between PBA perception and purchase intention*

329 To better understand PBA perceptions that may associate with purchase intention, we
 330 reexamined the data by correlating the number of times participants endorsed each attribute
 331 across the eight products with their PBA purchase intention. For context, we note that PBA
 332 purchase intention correlated positively with self-reported consumption of PBA, health values,
 333 green consumer values, and trust in the food system, and negatively with self-reported
 334 consumption of animal-derived foods, meat reduction attitudes, and fear of food technology
 335 (Supplemental table 4). PBA purchase intention had little correlation with perception of animal-
 336 derived foods, with only the terms “wholesome” ($p = 0.006, \rho = -0.166$) and “healthy” ($p =$
 337 $0.009, \rho = -0.158$) being weakly correlated with PBA purchase intention (Supplemental table 5).
 338 This observation suggests that there were few inherent differences in how PBA purchase
 339 intention influenced how participants used the terms or how they viewed conventional, animal-
 340 derived foods.

341 **Table 3: Spearman’s rank correlations (ρ) between PBA image descriptor endorsement and PBA purchase**
 342 **intention.**

	ρ	p-value
Tasty	0.649	<0.001
Familiar	0.394	<0.001
Good protein source	0.37	<0.001
Convenient	0.32	<0.001
Healthy	0.308	<0.001
Wholesome	0.251	<0.001
Natural	0.242	<0.001
Adventurous	0.228	<0.001
Eco-friendly	0.209	<0.001

Modern	0.184	0.002
Traditional	0.134	0.027
Cheap	0.083	0.173
Expensive	-0.063	0.304
Processed	-0.156	0.010
Unhealthy	-0.296	<0.001
Boring	-0.319	<0.001
Bland	-0.385	<0.001
Unnatural	-0.556	<0.001

343

344

345 PBA purchase intention had the strongest positive correlation with the term “Tasty” ($\rho =$
346 0.649) and strongest negative correlation with “Unnatural” ($\rho = -0.556$). Moderate ($\rho > 0.2$, (de
347 Winter et al., 2016) positive associations were observed with the terms “Familiar”, “Good source
348 of protein”, “Convenient”, “Healthy”, “Wholesome”, “Natural”, “Adventurous”, and “Eco-
349 friendly”; meanwhile, PBA purchase intention was moderately lower when participants
350 associated the products with terms “Bland”, “Boring”, and “Unhealthy”. Of note, the term
351 “processed” was only weakly ($\rho = -0.156$) correlated with PBA purchase intention. Interestingly,
352 correlations with terms associated with cost (i.e., “Expensive” and “Cheap”) were not
353 significantly correlated with PBA purchase intention, suggesting that price perception is not a
354 differentiator for individuals considering PBA product purchases.

355 *3.5 Person-related factors and perception of PBA*

356 To investigate the relationship between person-related factors and perceptions of PBA,
357 we conducted a stepwise multiple linear regression. Purchase intention of PBA was used as the
358 dependent variable and all demographic (age, gender, education, income) and person-related
359 factors (health value, green consumer values, trust in the food industry, food technology
360 neophobia, meat reduction) were included as predictor variables. For comparison, the same

361 model was run for purchase intention of animal-derived products. This exploratory analysis can
362 provide insights into how person-related characteristics influence perception of PBA foods in
363 contrast to animal-derived foods. The results and final model are provided in Table 4.

364

365

366 **Table 4: Stepwise multiple linear regression model of the variables predicting purchase intention for animal-**
 367 **derived (AD) and PBA products.**

Outcome	Predictor variable	Std B	t	Sig.	95% Confidence Interval for Std B		Collinearity Statistics	
					Lower	Upper	Tolerance	VIF
Purchase Intention AD	AD consumption	0.547	11.263	<0.001	0.451	0.642	0.779	1.284
	Meat consumption attitude	0.232	4.696	<0.001	0.135	0.329	0.751	1.331
	Trust	0.167	3.781	<0.001	0.081	0.254	0.940	1.064
	Education	-0.110	-2.532	0.012	-0.196	-0.025	0.969	1.032
	Gender	0.102	2.298	0.022	0.015	0.190	0.929	1.076
	Model	P<0.001, R ² = 0.515						
Purchase Intention PBA	PBA consumption	0.454	10.134	<0.001	0.366	0.542	0.811	1.233
	Food technology neophobia	-0.351	-7.606	<0.001	-0.442	-0.260	0.766	1.306
	AD consumption	-0.150	-3.462	0.001	-0.235	-0.065	0.870	1.150
	Trust	0.142	3.181	0.002	0.054	0.230	0.816	1.225
	Model	P<0.001, R ² = 0.569						

368

369 Purchase intention for animal-derived products was positively predicted by the
 370 consumption frequency of animal products, meat consumption attitude (higher indicates more
 371 meat attached), and trust in the food system. Males and those with a lower education were also
 372 more likely to have a higher purchase intention for animal-derived products. Together, these
 373 demographic and person-related factors explain 51.5% of the variation in the reported purchase
 374 intention of all animal-derived foods in the study.

375 Conversely, purchase intention of PBA was associated with self-reported consumption
 376 frequency of both PBA (positively) and animal products (negatively), FTN, and trust. This model
 377 explained 56.9% of the variation in the reported purchase intention for all PBA foods. Greater
 378 FTN and more frequent consumption of animal foods were both negatively associated with
 379 purchase intention of PBA. Neither health values nor green consumer values were significant in

380 either model (see Table 4). Overall, with a sample of over 100 respondents and a lack of
381 multicollinearity, both models were significant at $p < 0.001$ with R^2 values exceeding 50%,
382 suggesting good model fit (Wang et al., 2016).

383 **4. Discussion**

384 The results of the present study provide new insights into consumer perceptions of PBA.
385 To better characterize how consumers describe the PBA category, we assessed the attributes that
386 participants associate with PBA products and the animal-derived foods they mimic. Consistent
387 with findings from sorting studies (Chollet et al., 2022; Etter et al., 2024; Hoek et al., 2011; van
388 der Meer et al., 2023), we demonstrate that PBA (both meat and dairy) are perceived as a distinct
389 category rather than as replacements for animal-derived foods. Based on the product clustering
390 observations, it is likely that participants primarily viewed the foods based on origin (plant-based
391 vs animal) rather than how the product is used. Although we chose to analyze descriptor
392 endorsement across all PBA to better describe the category generally, we note that plant-based
393 categories (e.g., meat, dairy) are perceived differently among some consumers segments
394 (Cardello et al., 2022). Further investigation is merited to differentiate how various consumer
395 segments describe the PBA sub-categories.

396 Interestingly, traditional plant-based products (tofu and veggie burger) clustered closer to
397 plant-based milk and plant-based yogurt, two products with more established markets. Similar to
398 the findings by Etter and others (2024), who found that more established plant-based dairy
399 products clustered closer to traditional products, participants in the present study may have
400 perceived familiar PBA products as more similar to traditional products.

401 *4.1. Perceptions of taste, eco-friendliness, and health*

402 Our finding that participants rated PBA as less tasty than their animal-derived analogs,
403 and that “bland” had the second highest PBA purchase intention penalty was unsurprising, given
404 that taste is a well-documented barrier to PBA adoption (Onwezen et al., 2021). Although “tasty”
405 lifted animal-derived purchase intention more than any other description, the descriptors
406 “healthy”, “good source of protein”, “modern”, and “eco-friendly” lifted PBA purchase
407 intention. This finding is in agreement with others who found that PBA adopters do so for
408 reasons other than taste (Knaapila et al., 2022).

409 While others have identified price as a barrier to PBA (Giacalone et al., 2022;
410 International Food Information Council, 2023), cost was a less prominent barrier in the current
411 study. Although the term “expensive” penalized PBA purchase intention, it was less impactful
412 than “bland” and “unnatural”. Furthermore, “expensive” perception was not correlated with PBA
413 purchase intention, consistent with findings in plant-based milk alternatives (Martínez-Padilla et
414 al., 2023). Together, this suggests that factors other than price (namely, unnaturalness and taste)
415 differentiate PBA products from their animal-derived counterparts. Future studies are needed to
416 examine how perceptions of “expensive” align with the actual cost of PBA compared to animal-
417 derived foods.

418 Similar to the study by de Oliveira Padilha et al. (2022), PBAs were perceived as more
419 eco-friendly than the animal derived foods they mimicked. Despite consumers tending to
420 overestimate the environmental impact of PBA and underestimate environmental impact of
421 animal derived products (Hartmann et al., 2022), we demonstrate that consumers consistently
422 perceive PBA as more eco-friendly than their counterparts.

423 We found that PBA foods are generally seen as more neutral on health relative to the
424 foods they mimic. As a category, PBA were endorsed as “unhealthy” less than 10% of the time,
425 while they were viewed as “healthy” only 30% of the time. Furthermore, while animal-derived
426 sausage and chicken nuggets were consistently viewed as “unhealthy”, the PBA versions were
427 not seen as strongly healthy or unhealthy. Likewise, we observed a similar trend for traditionally
428 healthy products – animal-derived chicken was seen as “healthy”, but PBA chicken was neutral.
429 This supports previous findings that meat alternatives are perceived healthier when they replace
430 traditionally unhealthy products such as beef burgers, chicken nuggets, or sausage (Siegrist &
431 Hartmann, 2020b; Vural et al., 2023). Considering the observations that a) processed foods are
432 seen as less healthy regardless of whether the product is meat or a meat substitute (Hartmann et
433 al., 2022); b) less processed animal-derived products (i.e., chicken breast, salmon) are seen as
434 healthier than PBA products (de Oliveira Padilha et al., 2022; Siegrist & Hartmann, 2020b); and
435 c) PBAs may be more successful when they replace a food that is already seen as processed, like
436 sausage and nuggets (Michel, Hartmann, et al., 2021) – we suggest that perceived processing
437 may mediate the perceived healthiness/unhealthiness of PBA. This study did not consider
438 specific nutrients or nutritional profiles, thus, more work is needed to determine how nutritional
439 composition and labelling, along with ingredients, may mediate this relationship and perceived
440 PBA healthiness.

441 *4.2. Perceptions of processed and unnatural*

442 Although participants associated the term “processed” with PBAs more than any other
443 descriptor, the term was not unique to PBAs. For example, chicken nuggets and sausage were the
444 main products associated with the second dimension, which was constructed primarily by the

445 term “unhealthy” followed by “processed” (Supplemental Table 3). Furthermore, “processed”
446 clustered with “unhealthy”, while “unnatural” clearly clustered with PBA descriptors (Figure 2),
447 and “processed” perception was only weakly correlated with PBA purchase intention.
448 Considering that consumers generally accept familiar processed products and associate them
449 with being less healthy, the term “processed” may not be a distinguishing attribute that penalizes
450 PBAs relative to animal-derived products. Alternatively, we posit that perceived unnaturalness
451 may be a stronger differentiating characteristic.

452 “Unnatural” endorsement had a larger penalty on PBA purchase intention than any other
453 descriptor, including “bland”. As taste is often considered one of the prevailing explanations for
454 PBA rejection (Onwezen et al., 2021), the observation that “unnatural” penalized PBA purchase
455 intention more than “bland” merits further discussion. Together with our finding that the fear of
456 food technology negatively predicted PBA purchase intention (Table 4), we suggest that the
457 perception of PBAs as either modern or unnatural may be a key differentiator of PBA
458 purchasers. The unnatural perception may further challenge the adoption of PBA due to the
459 negative impact it has on other attributes. For example, the unnatural perception may contradict
460 the healthy and sustainable positioning of PBA, as perceived naturalness of PBA correlates with
461 perceived health and environmental friendliness (Hartmann et al., 2022). Furthermore,
462 consumers perceive the term natural as healthier, tastier, higher quality and more ecofriendly
463 (Magnier et al., 2016; Román et al., 2017). Our findings build on this prior work, demonstrating
464 that PBAs are seen by many consumers as unnatural, and that this perception may diminish the
465 positive attributes of tasty, healthy, and eco-friendly.

466 *4.3. Person-related factors predicting acceptance*

467 In addition to product perception, PBA acceptance is also associated with person-related
468 factors such as demographic variables, FTN, meat attachment, and personal values (Jahn et al.,
469 2021; Onwezen et al., 2021). As a secondary objective, we explored the relative contribution of
470 various person-related factors to PBA purchase intention. Although others have found
471 differences in the acceptance and purchase of PBA based on age, gender, income, and education
472 (Chia et al., 2024; Neuhofer & Lusk, 2022, 2023), we did not observe an effect. Our study
473 revealed that attitudes towards meat reduction, green consumer values, and health values did not
474 significantly associate with PBA purchase intention. Besides participants' consumption of
475 animal-derived products and PBA, only FTN and trust in the food industry was associated with
476 PBA purchase intention. Our finding aligns with others who have found that FTN is a substantial
477 barrier to willingness to try, buy, and pay for PBA (de Koning et al., 2020).

478 In addition to FTN, trust has been identified as a barrier to the acceptance, consumption,
479 and behavioral intentions of PBA (Faber et al., 2024; Hwang et al., 2020; Kerslake et al., 2022;
480 McBey et al., 2019; Varela et al., 2022). Similarly, the intention to consume PBA is higher
481 among those who trust food regulators and manufacturers (Begho et al., 2023). Our findings are
482 aligned with previous results, identifying that trust in the food industry is negatively associated
483 with PBA purchase intention. Ultimately, consumers' trust in the food industry, including
484 regulators and manufacturers, is an essential part of purchase intention and acceptance of PBA.

485 There have been conflicting results as to whether meat attachment is associated with
486 negative attitudes towards PBA. There is evidence suggesting that unwillingness to reduce meat
487 consumption is associated with no or low motivation to consume a sustainable diet (Chen, 2023;
488 Graça et al., 2015). Participants in our study, who were more open to meat reduction, had a

489 higher purchase intention of plant-based products. The relationship between meat attitudes and
490 plant-based eating may vary by product, as others have found that for a plant-based burger,
491 attitudes towards meat reduction become less important, compared to other person-related traits,
492 such as green values (Moussaoui et al., 2023). Further investigation is needed to provide a more
493 complete understanding around person-related factors, such as motivations to reduce meat,
494 values (health and sustainability), and attitudes (trust) that drive consumer behavior related to
495 PBA and sustainable diets. It is expected that these relationships may vary for specific product
496 types.

497 *4.4. Strengths, limitations, methodological considerations*

498 Our innovative approach provides insights about how consumers view the PBA
499 category. A unique contribution of this study is the inclusion of a broad range of PBA products
500 that represent various levels of processing and multiple categories. Combining the perceptions of
501 individual PBA products provides a more realistic characterization of the category than asking
502 about PBAs generally. Furthermore, we demonstrate how disparate perceptions of unnatural and
503 processed may partially explain why consumers view PBAs as distinct from the animal-derived
504 products they imitate. The results of this study expand PBA research by demonstrating the
505 importance of addressing the unnatural perception. While these findings provide new insights for
506 the PBA category, distinct relationships may differ within PBA sub-categories. Additional
507 studies are needed to explore how perceived processing and unnaturalness influence PBA
508 acceptance. For example, alternatives to chicken nuggets vs. chicken breast would be viewed
509 differently due to the influence of perceived processing.

510 The present work should be interpreted in the context of its limitations. Although images
511 can put participants in a product-focused frame of mind, presenting them with actual food may
512 more accurately reflect real world judgments (Colla et al., 2021). We also note that
513 correspondence analysis is strongly influenced by the selection of terms and products. Our
514 selection of dichotomous pairs that consumers associate with either “good” or “bad” likely
515 explains a large amount of why PBA terms accounted for a large amount of the variation. We
516 may have observed different configurations had a larger variety of products and descriptive
517 terms been included.

518 **Conclusion and Recommendations**

519 Here, we confirm perceived taste as a barrier to PBA purchase intention. We identify,
520 perceived unnaturalness and processing of PBA products as important drivers of low acceptance.
521 Further, a lack of trust and high food technology neophobia are associated with low purchase
522 intention. Together, these data suggest that even if taste parity were achieved – which is the
523 current goal of PBA R&D and the recipient of billions of dollars of funding – consumers’
524 perceptions of unnaturalness would remain a barrier. This finding, if confirmed, suggests that
525 additional strategies outside of R&D alone are needed if PBA are to be successful. For example,
526 as naturalness has both functional (e.g., health and taste) and ideational (e.g., moral reason),
527 emphasizing the functional properties of PBA may help address the unnatural barrier (M. Li &
528 Chapman, 2012; Siegrist & Hartmann, 2020a). We recommend additional research to identify
529 strategies to address concerns regarding unnaturalness to support PBA adoption.

530

531 **CRedit authorship of contribution statement**

532 **Jonathan Kershaw:** Conceptualization, Methodology, Formal analysis, Investigation,
533 Resources, Writing—original draft preparation, Writing—review and editing, Supervision.

534 **Alissa Nolden:** Conceptualization, Methodology, Resources, Writing—original draft
535 preparation, Writing—review and editing. **Lydia Ellinger:** Methodology, Investigation,
536 Writing—original draft preparation, Writing—review and editing. **Nomzamo Dlamini:** Formal
537 analysis, Investigation, Writing—original draft preparation, Writing—review and editing.

538 **Declaration of Competing Interest**

539 The Nolden Sensory Lab has received fees to conduct sensory tests for the food industry to
540 facilitate experiential learning for undergraduate and graduate students. None of these
541 organizations have had any role in study conception, design or interpretation, or the decision to
542 publish these data.

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547 **References**

548 Appiani, M., Cattaneo, C., & Laureati, M. (2023). Sensory properties and consumer acceptance
549 of plant-based meat, dairy, fish and eggs analogs: A systematic review. *Frontiers in*
550 *Sustainable Food Systems*, 7. <https://doi.org/10.3389/fsufs.2023.1268068>

551 Aschemann-Witzel, J., Gantriis, R. F., Fraga, P., & Perez-Cueto, F. J. A. (2021). Plant-based
552 food and protein trend from a business perspective: Markets, consumers, and the challenges
553 and opportunities in the future. *Critical Reviews in Food Science and Nutrition*, 61(18), 3119–
554 3128. <https://doi.org/10.1080/10408398.2020.1793730>

555 Battle, M., Pierce, B., Carter, M., Clarke, J., Fathman, L., Gertner, D., Ignaszewski, E., Kogar,
556 N., Leet-Otley, T., & Panescu, P. (2023). *2023 State of the Industry Report: Plant-based meat,*
557 *seafood, eggs, and dairy*. Good Food Institute. [https://gfi.org/wp-](https://gfi.org/wp-content/uploads/2024/05/2023-State-of-the-industry-report_Plant-based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIyMzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczOC4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE)
558 [content/uploads/2024/05/2023-State-of-the-industry-report_Plant-](https://gfi.org/wp-content/uploads/2024/05/2023-State-of-the-industry-report_Plant-based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIyMzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczOC4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE)
559 [based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIy](https://gfi.org/wp-content/uploads/2024/05/2023-State-of-the-industry-report_Plant-based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIyMzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczOC4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE)
560 [MzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczO](https://gfi.org/wp-content/uploads/2024/05/2023-State-of-the-industry-report_Plant-based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIyMzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczOC4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE)
561 [C4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-](https://gfi.org/wp-content/uploads/2024/05/2023-State-of-the-industry-report_Plant-based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIyMzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczOC4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE)
562 [O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE](https://gfi.org/wp-content/uploads/2024/05/2023-State-of-the-industry-report_Plant-based.pdf?_gl=1%2A1vw5qd0%2A_up%2AMQ.%2A_ga%2AMTYwNTY0MTIyOS4xNzIyMzUwNjkw%2A_ga_TT1WCK8ETL%2AMTcyMjM1MDY4Ny4xLjEuMTcyMjM1MDczOC4wLjAuMA..&gclid=CjwKCAjwnqK1BhBvEiwAi7o0X6h2JLsG-O4seFqYZtG8gHxgZkNuDetGBjx43rQzYBIB6E5ahjGJqhoC_9oQAvD_BwE)

563 Begho, T., Odeniyi, K., & Fadare, O. (2023). Toward acceptance of future foods: The role of
564 trust and perception in consumption intentions of plant-based meat alternatives. *British Food*
565 *Journal*, 125(7), 2392–2406.

566 Blechert, J., Meule, A., Busch, N. A., & Ohla, K. (2014). Food-pics: An image database for
567 experimental research on eating and appetite. *Frontiers in Psychology*, 5.
568 <https://doi.org/10.3389/fpsyg.2014.00617>

569 Cardello, A. V., Llobell, F., Giacalone, D., Chheang, S. L., & Jaeger, S. R. (2022). Consumer
570 Preference Segments for Plant-Based Foods: The Role of Product Category. *Foods*, 11(19),
571 Article 19. <https://doi.org/10.3390/foods11193059>

572 Carey, C. N., Paquette, M., Sahye-Pudaruth, S., Dadvar, A., Dinh, D., Khodabandehlou, K.,
573 Liang, F., Mishra, E., Sidhu, M., Brown, R., Tandon, S., Wanyan, J., Bazinet, R. P., Hanley,
574 A. J., Malik, V., Sievenpiper, J. L., & Jenkins, D. JA. (2023). The Environmental
575 Sustainability of Plant-Based Dietary Patterns: A Scoping Review. *The Journal of Nutrition*,
576 *153*(3), 857–869. <https://doi.org/10.1016/j.tjnut.2023.02.001>

577 *Census Bureau Data*. (n.d.). Retrieved February 6, 2025, from <https://data.census.gov/>

578 Chen, M.-F. (2023). Consumer food choice motives and willingness to try plant-based meat:
579 Moderating effect of meat attachment. *British Food Journal*, *126*(3), 1301–1324.
580 <https://doi.org/10.1108/BFJ-04-2023-0330>

581 Chia, A., Shou, Y., Wong, N. M. Y., Cameron-Smith, D., Sim, X., Van Dam, R. M., & Chong,
582 M. F.-F. (2024). Complexity of consumer acceptance to alternative protein foods in a
583 multiethnic Asian population: A comparison of plant-based meat alternatives, cultured meat,
584 and insect-based products. *Food Quality and Preference*, *114*, 105102.
585 <https://doi.org/10.1016/j.foodqual.2024.105102>

586 Chollet, S., Sénécal, C., Woelki, L., Cortesi, A., Fifi, V., Arvisenet, G., & Valentin, D. (2022).
587 How protein containing foods are represented in memory? A categorization study. *Food*
588 *Quality and Preference*, *96*, 104381. <https://doi.org/10.1016/j.foodqual.2021.104381>

589 Colla, K., Keast, R., Hartley, I., & Liem, D. G. (2021). Using an online photo based
590 questionnaire to predict tasted liking and amount sampled of familiar and unfamiliar foods by

591 female nutrition students. *Journal of Sensory Studies*, 36(1), e12614.
592 <https://doi.org/10.1111/joss.12614>

593 Cornelissen, K., & Piqueras-Fiszman, B. (2023). Consumers' perception of cultured meat
594 relative to other meat alternatives and meat itself: A segmentation study. *Journal of Food*
595 *Science*, 88(S1), A91–A105. <https://doi.org/10.1111/1750-3841.16372>

596 Cox, D. N., & Evans, G. (2008). Construction and validation of a psychometric scale to measure
597 consumers' fears of novel food technologies: The food technology neophobia scale. *Food*
598 *Quality and Preference*, 19(8), 704–710. <https://doi.org/10.1016/j.foodqual.2008.04.005>

599 de Koning, W., Dean, D., Vriesekoop, F., Aguiar, L. K., Anderson, M., Mongondry, P., Oppong-
600 Gyamfi, M., Urbano, B., Luciano, C. A. G., Jiang, B., Hao, W., Eastwick, E., Jiang, Z.
601 (Virgil), & Boereboom, A. (2020). Drivers and Inhibitors in the Acceptance of Meat
602 Alternatives: The Case of Plant and Insect-Based Proteins. *Foods*, 9(9), Article 9.
603 <https://doi.org/10.3390/foods9091292>

604 de Oliveira Padilha, L. G., Malek, L., & Umberger, W. J. (2022). Consumers' attitudes towards
605 lab-grown meat, conventionally raised meat and plant-based protein alternatives. *Food*
606 *Quality and Preference*, 99, 104573. <https://doi.org/10.1016/j.foodqual.2022.104573>

607 de Winter, J., Gosling, S., & Potter, J. (2016). Comparing the Pearson and Spearman Correlation
608 Coefficients Across Distributions and Sample Sizes: A Tutorial Using Simulations and
609 Empirical Data. *PSYCHOLOGICAL METHODS*, 21(3), 273–290.
610 <https://doi.org/10.1037/met0000079>

611 Djekic, I. (2015). Environmental Impact of Meat Industry – Current Status and Future
612 Perspectives. *Procedia Food Science*, 5, 61–64. <https://doi.org/10.1016/j.profoo.2015.09.025>

613 Etter, B., Michel, F., & Siegrist, M. (2024). Consumers’ categorizations of dairy products and
614 plant-based milk, yogurt, and cheese alternatives. *Appetite*, 203, 107658.
615 <https://doi.org/10.1016/j.appet.2024.107658>

616 Evans, G., de Challemaison, B., & Cox, D. N. (2010). Consumers’ ratings of the natural and
617 unnatural qualities of foods. *Appetite*, 54(3), 557–563.
618 <https://doi.org/10.1016/j.appet.2010.02.014>

619 Faber, I., Rini, L., Schouteten, J. J., Bom Frøst, M., De Steur, H., & Perez-Cueto, F. J. A. (2024).
620 The mediating role of barriers and trust on the intentions to consume plant-based foods in
621 Europe. *Food Quality and Preference*, 114, 105101.
622 <https://doi.org/10.1016/j.foodqual.2024.105101>

623 Faria, A. A., & Kang, J. (2022). It’s not just about the food: Motivators of food patterns and their
624 link with sustainable food neophobia. *Appetite*, 174, 106008.
625 <https://doi.org/10.1016/j.appet.2022.106008>

626 Fiorentini, M., Kinchla, A. J., & Nolden, A. A. (2020). Role of Sensory Evaluation in Consumer
627 Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. *Foods*,
628 9(9), Article 9. <https://doi.org/10.3390/foods9091334>

629 Giacalone, D., Clausen, M. P., & Jaeger, S. R. (2022). Understanding barriers to consumption of
630 plant-based foods and beverages: Insights from sensory and consumer science. *Current*
631 *Opinion in Food Science*, 48, 100919. <https://doi.org/10.1016/j.cofs.2022.100919>

632 Graça, J., Calheiros, M. M., & Oliveira, A. (2015). Attached to meat? (Un)Willingness and
633 intentions to adopt a more plant-based diet. *Appetite*, 95, 113–125.
634 <https://doi.org/10.1016/j.appet.2015.06.024>

635 Hartmann, C., Furtwaengler, P., & Siegrist, M. (2022). Consumers' evaluation of the
636 environmental friendliness, healthiness and naturalness of meat, meat substitutes, and other
637 protein-rich foods. *Food Quality and Preference*, 97, 104486.
638 <https://doi.org/10.1016/j.foodqual.2021.104486>

639 Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable
640 protein consumption: A systematic review. *Trends in Food Science & Technology*, 61, 11–25.
641 <https://doi.org/10.1016/j.tifs.2016.12.006>

642 Haws, K. L., Winterich, K. P., & Naylor, R. W. (2014). Seeing the world through GREEN-tinted
643 glasses: Green consumption values and responses to environmentally friendly products.
644 *Journal of Consumer Psychology*, 24(3), 336–354. <https://doi.org/10.1016/j.jcps.2013.11.002>

645 Hoek, A. C., van Boekel, M. A. J. S., Voordouw, J., & Luning, P. A. (2011). Identification of
646 new food alternatives: How do consumers categorize meat and meat substitutes? *Food Quality*
647 *and Preference*, 22(4), 371–383. <https://doi.org/10.1016/j.foodqual.2011.01.008>

648 Hwang, J., You, J., Moon, J., & Jeong, J. (2020). Factors Affecting Consumers' Alternative
649 Meats Buying Intentions: Plant-Based Meat Alternative and Cultured Meat. *Sustainability*,
650 12(14), Article 14. <https://doi.org/10.3390/su12145662>

651 International Food Information Council. (2023). *Innovations in Alternative Proteins:
652 Understanding the Viewpoints and Purchasing Behaviors of U.S. Meat Eaters*.

653 Ismail, I., Hwang, Y.-H., & Joo, S.-T. (2020). Meat analog as future food: A review. *Journal of
654 Animal Science and Technology*, 62(2), 111–120. <https://doi.org/10.5187/jast.2020.62.2.111>

655 Jaeger, S. R., Cardello, A. V., Jin, D., Ryan, G. S., & Giacalone, D. (2023). Consumer perception
656 of plant-based yoghurt: Sensory drivers of liking and emotional, holistic and conceptual
657 associations. *Food Research International*, 167, 112666.
658 <https://doi.org/10.1016/j.foodres.2023.112666>

659 Jahn, S., Furchheim, P., & Strässner, A.-M. (2021). Plant-Based Meat Alternatives: Motivational
660 Adoption Barriers and Solutions. *Sustainability*, 13(23), Article 23.
661 <https://doi.org/10.3390/su132313271>

662 Jiang, X., Chen, X., & Wu, L. (2024). Chinese consumers' valuation for prepared plant-based
663 meat products: Does environmental information matter? *Journal of Food Science*, 89(9),
664 5823–5840. <https://doi.org/10.1111/1750-3841.17279>

665 Keoleian, G. A., & Heller, M. C. (2018). *Beyond Meat's beyond burger life cycle assessment: A
666 detailed comparison between a plant-based and an animal-based protein source*.

667 Kerslake, E., Kemper, J. A., & Conroy, D. (2022). What's your beef with meat substitutes?
668 Exploring barriers and facilitators for meat substitutes in omnivores, vegetarians, and vegans.
669 *Appetite*, 170, 105864. <https://doi.org/10.1016/j.appet.2021.105864>

670 Knaapila, A., Michel, F., Jouppila, K., Sontag-Strohm, T., & Piironen, V. (2022). Millennials'
671 Consumption of and Attitudes toward Meat and Plant-Based Meat Alternatives by Consumer
672 Segment in Finland. *Foods*, 11(3), Article 3. <https://doi.org/10.3390/foods11030456>

673 Kühn, D., Profeta, A., Krikser, T., & Heinz, V. (2023). Adaption of the meat attachment scale
674 (MEAS) to Germany: Interplay with food neophobia, preference for organic foods, social trust
675 and trust in food technology innovations. *Agricultural and Food Economics*, 11(1), 38.
676 <https://doi.org/10.1186/s40100-023-00278-3>

677 Li, J., Silver, C., Gómez, M. I., Milstein, M., & Sogari, G. (2023). Factors influencing consumer
678 purchase intent for meat and meat substitutes. *Future Foods*, 7, 100236.
679 <https://doi.org/10.1016/j.fufo.2023.100236>

680 Li, M., & Chapman, G. B. (2012). Why Do People Like Natural? Instrumental and Ideational
681 Bases for the Naturalness Preference. *Journal of Applied Social Psychology*, 42(12), 2859–
682 2878. <https://doi.org/10.1111/j.1559-1816.2012.00964.x>

683 Loken, B., Barsalou, L. W., & Joiner, C. (2008). Categorization Theory and Research in
684 Consumer Psychology: Category Representation and Category-Based Inference: Barbara
685 Loken, Lawrence W. Barsalou, and Christopher Joiner. In *Handbook of Consumer*
686 *Psychology*. Routledge.

687 Magnier, L., Schoormans, J., & Mugge, R. (2016). Judging a product by its cover: Packaging
688 sustainability and perceptions of quality in food products. *Food Quality and Preference*, 53,
689 132–142. <https://doi.org/10.1016/j.foodqual.2016.06.006>

690 Martínez-Padilla, E., Faber, I., Petersen, I. L., & Vargas-Bello-Pérez, E. (2023). Perceptions
691 toward Plant-Based Milk Alternatives among Young Adult Consumers and Non-Consumers
692 in Denmark: An Exploratory Study. *Foods*, 12(2), Article 2.
693 <https://doi.org/10.3390/foods12020385>

694 McBey, D., Watts, D., & Johnstone, A. M. (2019). Nudging, formulating new products, and the
695 lifecourse: A qualitative assessment of the viability of three methods for reducing Scottish
696 meat consumption for health, ethical, and environmental reasons. *Appetite*, 142, 104349.
697 <https://doi.org/10.1016/j.appet.2019.104349>

698 Meyners, M., Castura, J. C., & Carr, B. T. (2013). Existing and new approaches for the analysis
699 of CATA data. *Food Quality and Preference*, 30(2), 309–319.
700 <https://doi.org/10.1016/j.foodqual.2013.06.010>

701 Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and
702 acceptance of meat and plant-based meat alternatives. *Food Quality and Preference*, 87,
703 104063. <https://doi.org/10.1016/j.foodqual.2020.104063>

704 Moss, R., LeBlanc, J., Gorman, M., Ritchie, C., Duizer, L., & McSweeney, M. B. (2023). A
705 Prospective Review of the Sensory Properties of Plant-Based Dairy and Meat Alternatives
706 with a Focus on Texture. *Foods*, 12(8), Article 8. <https://doi.org/10.3390/foods12081709>

707 Moussaoui, D., Torres-Moreno, M., Tárrega, A., Martí, J., López-Font, G., & Chaya, C. (2023).
708 Evaluation of consumers' response to plant-based burgers according to their attitude towards
709 meat reduction. *Food Quality and Preference*, *110*, 104955.
710 <https://doi.org/10.1016/j.foodqual.2023.104955>

711 Neff, R. A., Edwards, D., Palmer, A., Ramsing, R., Righter, A., & Wolfson, J. (2018). Reducing
712 meat consumption in the USA: A nationally representative survey of attitudes and behaviours.
713 *Public Health Nutrition*, *21*(10), 1835–1844. <https://doi.org/10.1017/S1368980017004190>

714 Neuhofer, Z. T., & Lusk, J. L. (2022). Most plant-based meat alternative buyers also buy meat:
715 An analysis of household demographics, habit formation, and buying behavior among meat
716 alternative buyers. *Scientific Reports*, *12*(1), Article 1. [https://doi.org/10.1038/s41598-022-](https://doi.org/10.1038/s41598-022-16996-5)
717 [16996-5](https://doi.org/10.1038/s41598-022-16996-5)

718 Neuhofer, Z. T., & Lusk, J. L. (Eds.). (2023). *Impacts of Variety-Seeking, Substitution, and*
719 *Demographics on Demand for Plant-Based Meat Alternatives*.

720 Neville, M., Tarrega, A., Hewson, L., & Foster, T. (2017). Consumer-orientated development of
721 hybrid beef burger and sausage analogues. *Food Science & Nutrition*, *5*(4), 852–864.
722 <https://doi.org/10.1002/fsn3.466>

723 Onwezen, M. C., Bouwman, E. P., Reinders, M. J., & Dagevos, H. (2021). A systematic review
724 on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat
725 alternatives, and cultured meat. *Appetite*, *159*, 105058.
726 <https://doi.org/10.1016/j.appet.2020.105058>

727 Possidónio, C., Prada, M., Graça, J., & Piazza, J. (2021). Consumer perceptions of conventional
728 and alternative protein sources: A mixed-methods approach with meal and product framing.
729 *Appetite*, 156, 104860. <https://doi.org/10.1016/j.appet.2020.104860>

730 Román, S., Sánchez-Siles, L. M., & Siegrist, M. (2017). The importance of food naturalness for
731 consumers: Results of a systematic review. *Trends in Food Science & Technology*, 67, 44–57.
732 <https://doi.org/10.1016/j.tifs.2017.06.010>

733 Rööös, E., Sundberg, C., Tidåker, P., Strid, I., & Hansson, P.-A. (2013). Can carbon footprint
734 serve as an indicator of the environmental impact of meat production? *Ecological Indicators*,
735 24, 573–581. <https://doi.org/10.1016/j.ecolind.2012.08.004>

736 Senaviratna, N. A. M. R., & A. Cooray, T. M. J. (2019). Diagnosing Multicollinearity of Logistic
737 Regression Model. *Asian Journal of Probability and Statistics*, 5(2), 1–9.
738 <https://doi.org/10.9734/ajpas/2019/v5i230132>

739 Siegrist, M., & Hartmann, C. (2020a). Consumer acceptance of novel food technologies. *Nature*
740 *Food*, 1(6), 343–350. <https://doi.org/10.1038/s43016-020-0094-x>

741 Siegrist, M., & Hartmann, C. (2020b). Perceived naturalness, disgust, trust and food neophobia
742 as predictors of cultured meat acceptance in ten countries. *Appetite*, 155, 104814.
743 <https://doi.org/10.1016/j.appet.2020.104814>

744 Spendrup, S., & Hovmalm, H. P. (2022). Consumer attitudes and beliefs towards plant-based
745 food in different degrees of processing – The case of Sweden. *Food Quality and Preference*,
746 102, 104673. <https://doi.org/10.1016/j.foodqual.2022.104673>

747 Swann, C., & Kelly, M. (2023). Disruption in the meat industry: New technologies in nonmeat
748 substitutes. *Business Economics (Cleveland, Ohio)*, 58(1), 42–60.
749 <https://doi.org/10.1057/s11369-023-00302-w>

750 Thorbecke, M., & Dettling, J. (2019). Carbon footprint evaluation of regenerative grazing at
751 White Oak Pastures. *Boston (MA): Quantis*.

752 van der Meer, M., Fischer, A. R. H., & Onwezen, M. C. (2023). Same strategies – different
753 categories: An explorative card-sort study of plant-based proteins comparing omnivores,
754 flexitarians, vegetarians and vegans. *Appetite*, 180, 106315.
755 <https://doi.org/10.1016/j.appet.2022.106315>

756 van der Weele, C., Feindt, P., Jan van der Goot, A., van Mierlo, B., & van Boekel, M. (2019).
757 Meat alternatives: An integrative comparison. *Trends in Food Science & Technology*, 88,
758 505–512. <https://doi.org/10.1016/j.tifs.2019.04.018>

759 Varela, P., Arvisenet, G., Gonera, A., Myhrer, K. S., Fifi, V., & Valentin, D. (2022). Meat
760 replacer? No thanks! The clash between naturalness and processing: An explorative study of
761 the perception of plant-based foods. *Appetite*, 169, 105793.
762 <https://doi.org/10.1016/j.appet.2021.105793>

763 Vural, Y., Ferriday, D., & Rogers, P. J. (2023). Consumers' attitudes towards alternatives to
764 conventional meat products: Expectations about taste and satisfaction, and the role of disgust.
765 *Appetite*, 181, 106394. <https://doi.org/10.1016/j.appet.2022.106394>

766 Wang, M., Wright, J., Brownlee, A., & Buswell, R. (2016). A comparison of approaches to
767 stepwise regression on variables sensitivities in building simulation and analysis. *Energy and*
768 *Buildings*, 127, 313–326. <https://doi.org/10.1016/j.enbuild.2016.05.065>

769 Wendt, M.-C., & Weinrich, R. (2023). A systematic review of consumer studies applying the
770 Food Technology Neophobia Scale: Lessons and applications. *Food Quality and Preference*,
771 106, 104811. <https://doi.org/10.1016/j.foodqual.2023.104811>

772