

Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

Article

Accepted Version

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Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers --Manuscript Draft--

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Abstract:	<p>This study assessed the effect of providing information on the consumers' sensory evaluation of three burgers: 100% beef, 100% plant-based and a hybrid (60% beef and 40% vegetables). A total of 99 UK consumers with balanced age and gender were recruited. Consumers assessed the burger products under blind, expected and informed conditions and answered questions on liking, Check-all-that-apply (CATA), willingness to buy (WTB) and willingness to pay (WTP) and provided free text comments. Results show that consumers are positive towards hybrid burgers, in terms of overall acceptability, purchase intent, willingness to pay and subjective comments. Hybrid meat products could represent an effective way for consumers to lower their meat consumption without compromising too much on the sensory quality and could represent a transition product to a more plant-based diet. These results are valuable and should inform future marketing, labelling and reformulation efforts of new hybrid meat product launches.</p>
Suggested Reviewers:	Giovanni Sogari giovanni.sogari@unipr.it Adriano Profeta a.profeta@dil-ev.de Amparo Tarrega atarrega@iata.csic.es
Response to Reviewers:	Please see attached file.

Manuscript Number: FQAP-D-21-00483R1

Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

Reviewer comments:

Reviewer #2: Dear authors,

Thank you for this much improved manuscript!

My main comment still goes to how you handle the WTP data. It's my understanding that you have several observations by each participant which would mean that you ultimately should account for within-subject heterogeneity under that you have repeated measures. The source of such variability in the product valuation can also relate to the condition under which the WTP was provided. I then do not see your analysis as adequate for the purpose that you are using it (and as presented in Table 4). The question should be about differences in WTP between product and conditions, while accounting for the within-subject value heterogeneity. This can readily be analyzed through the use of a multi-level model with proper account for fixed and random variables.

The authors thank the reviewer for this comment. The analysis has now been changed, so table 4 reports only the purchase intent for the three burgers in the three conditions and WTP has been removed. The variations in main and interaction effects under different conditions are now shown in Table 5, 6 and Figure 1 on WTP. Table 5 shows the results of a two-way repeated measures ANOVA, where samples and conditions are considered together rather than separately (as it was done previously). Table 6 shows for WPT the main effects (sample and condition) and interaction effects (sample * condition). Figure 1 shows visually how the WTP changed for the 3 burgers depending on the condition. In the text the results are discussed in lines 315-356.

Minor comments:

I have the following comments to some of the Tables and Figures that I see as relevant to improve the readability:

Tables 2 to 4 as well as Table 7: please add information about which test that the significance levels refers to. And I do not follow the notes to these Tables in terms of how to interpret the letters supposedly indicating significance (or?).

Tests and significance levels have now been added for table 2 in lines 271-274, table 3 in lines 293-297, table 4 in lines 311-314, table 7 (now table 9) in lines 498-499.

Table 5: can you show proportions (relative) rather than frequencies (absolute) here? And I do not follow the note to this Table in terms of how to interpret the letters (a/b, and c). Which test does the significance levels refer to?

This has now been done in what was table 5 (now table 7), please see lines 409-413. The significance refers to Cochran's Q test.

Figure 1: please write out correspondance analysis in full instead of just CA.

This has now been done in line 461.

First sensory evaluation of beef vs plant-based vs hybrid burger (60:40 beef - veg)

99 UK consumers assessed the burgers under blind, expected and informed conditions

In the blind condition the hybrid burger scored highest for overall liking

Informed purchase intent was higher for hybrid burgers than plant-based burgers

Informed max WTP was similar for beef and hybrid burgers and higher than plant-based

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Effect of information on consumers' sensory evaluation of beef, plant-based and hybrid beef burgers

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Abstract

This study assessed the effect of providing information on the consumers' sensory evaluation of three burgers: 100% beef, 100% plant-based and a hybrid (60% beef and 40% vegetables). A total of 99 UK consumers with balanced age and gender were recruited. Consumers assessed the burgers under blind, expected and informed conditions and answered questions on liking, Check-all-that-apply (CATA), willingness to buy (WTB) and willingness to pay (WTP). In addition, under blind and informed conditions, consumers were asked to indicate their likes and dislikes about each sample. Results show that consumers are positive towards hybrid burgers, in terms of overall acceptability, purchase intent, WTP and subjective comments. Hybrid meat products could represent an effective way for consumers to lower their meat consumption without compromising too much on the sensory quality and could represent a transition product to a more plant-based diet. These results are valuable and should inform future marketing, labelling and reformulation efforts of new hybrid meat product launches.

Keywords: CATA, hybrid burgers, consumer sensory analysis, liking, information, beef

1. Introduction

High meat consumption rates in the United Kingdom (UK) (average of 80 g per person/day) (Dibb & Fitzpatrick, 2014) are evident of a prosperous meat market, estimated to be worth £4.8 billion by 2023 (Mintel, 2019).

However, scientists have proven that the excessive intake of meat can lead to several health issues. For example, the frequent consumption of red and processed meat may increase the incidence of heart and cardiovascular diseases, colorectal cancer, and type 2 diabetes (Lippi, Cervellin, & Mattiuzzi, 2014). However, despite the negative health effects of excessive consumption, many consumers are highly attached to meat (Graça, Calheiros, & Oliveira, 2015).

Only 2-3% of the UK population maintains a vegetarian or vegan diet (The Vegetarian Society, 2021) and very few meat-eaters intend to imminently remove meat from their diets (Bryant, 2019). As this represents a small proportion of people who can benefit from the associated health outcomes, it has been suggested that encouraging the majority of the

39 population to reduce their meat consumption would be more effective than successfully
40 persuading a minority to eliminate meat completely (Asher et al., 2014).

41 Hence, as a mean to facilitate the transition process from a meat-based diet to a diet with
42 higher plant-based food intake, several options have been developed to provide consumers
43 with an alternative to conventional meat products. One of these are the so-called 'hybrid
44 meat products', which can appease consumers with the familiar taste and texture of meat
45 products, whilst providing a superior nutritional profile for example by benefitting from
46 reduced salt and fat and increased fibre, vitamin, and mineral content. Hybrid meat
47 products refer to processed meat products which substitute a percentage of meat for the
48 inclusion of plant-based ingredients, allowing consumers to still consume meat, but
49 moderating the daily intake which should be limited to 70 g of processed meat person/day
50 and including at least 400 g of fruit and vegetables per day (NHS Digital, 2019). They may
51 also have the potential to encourage more consumers to cut meat entirely from their diets,
52 as consumers could decide to continue the transition towards a more plant-based diet and
53 try meat-free options too.

54 Another available alternative to conventional meat products are plant-based meat products,
55 also known as meat substitutes or analogues, which are made with proteins from plant-
56 based sources, such as soy, peas and beans, typically resembling the aesthetic qualities of
57 conventional meat products (Hoek, Luning, *et al.*, 2011).

58
59 1.1 Consumers' reaction to hybrid meat products and plant-based meat alternatives
60 Changing diets is a long-term process (Hoek et al., 2013), most effective when the changes
61 required do not significantly differ from consumers' previous behaviour (Ryan & Deci, 2000).
62 A qualitative synthesis review on attitudes towards reducing meat consumption indicates
63 consumers have difficulties imagining an alternative diet with low or no meat to their
64 current dietary patterns (Sanchez-Sabate, Badilla-Briones, & Sabaté, 2019). In fact, meat is
65 perceived as an important element in human's diet and the principal component of several
66 dishes which are rooted in culinary traditions worldwide (Weinrich, 2018).

67
68 With regard to the current commercially available meat alternatives, the literature available
69 on this topic shows that one of the main aspects limiting consumers in introducing these
70 products into their diet is their lack of taste compared to conventional meat products. In
71 fact, it is a commonly held belief by meat eaters that consuming healthier versions of meat
72 products or meat analogues might compromise taste (Reipurth, Hørby, Gregersen, Bonke, &
73 Cueto, 2019) and sensory expectations (Tuorila & Hartmann, 2020). Even when asked to
74 assume that meat and meat alternatives have the same taste in a hypothetical experimental
75 setting, consumers still chose the beef-based option, as they are sceptical that plant-based
76 meat may actually taste like real meat (Slade, 2018). This is also confirmed by some sensory
77 evaluation studies, which found that consumers still have strong tasting preferences for
78 conventional compared to plant-based meat analogues (Michel, Hartmann, & Siegrist,
79 2021). Neville, Tarrega, Hewson, and Foster (2017) tested the consumer acceptability of
80 conventional, hybrid and plant-based meat products and showed that meat and hybrid
81 meat products had the highest acceptance, whereas plant-based meat products were poorly
82 accepted because of the lack of "meaty flavour". Other research articles also showed that
83 providing consumers with information related to different characteristics of plant-based

84 meat affects their sensory perception. For example, the ingredients used to produce these
85 products were also found to influence consumers' evaluation. In fact, Chang, Moon, and
86 Balasubramanian (2012) discovered that the sensory experience and purchase likelihood of
87 plant-based meat alternatives was negatively affected when consumers were provided with
88 information regarding the soy ingredient contained in the plant-based burgers, meaning
89 that knowing the composition of these products influences consumers' behaviour.
90 On the other hand, other type of information, for example related to the benefits of plant-
91 based meat compared to conventional meat seem to mitigate the negative sensory
92 perception of these products and positively impact their purchase likelihood and willingness
93 to pay (WTP). For example, Ye and Mattila (2021) found that information on health and
94 social consequences of meat consumption increased consumers' preferences for plant-
95 based meat alternatives. Similarly, Weinrich (2018) concluded that communicating the
96 health benefits of meat substitutes may increase the market share for these products. Estell,
97 Hughes, and Grafenauer (2021) showed that health-related information such as 'high in
98 protein' and 'high in dietary fibre' in relation to plant-based meat alternatives increased
99 consumers' WTP compared to when the products were proposed without such information.

100
101 Regarding hybrid meat products, the literature on consumers' attitude towards these
102 products is still at its infant stage. Grasso and Jaworska (2020) showed that taste is one of
103 the most important and frequently reported factor in online reviews in relation to hybrid
104 meat products, underlining that sensory quality is still key in the development of these
105 products. Profeta et al. (2021) employed a choice experiment to compare conventional
106 meat burgers with two types of hybrid meat burgers (with different meat and vegetable
107 ratios) and a plant-based burger, showing that preferences and WTP were highest for the
108 meat burger, followed by the hybrid burger with a higher percentage of meat, the hybrid
109 burger with the lower percentage of meat and then by the plant-based burger.

110 Given the small amount of literature available on consumers' attitudes to meat alternatives
111 and hybrid meats, little is yet known on this topic. In particular, to the best of the authors'
112 knowledge, a study investigating the effects of sensory evaluation and information provision
113 on consumers' purchase likelihood and WTP, testing together conventional beef burgers,
114 plant-based and hybrid burgers, is still missing. This research aims to fill this void by
115 conducting a consumer sensory evaluation of these products under blind, expected and
116 informed conditions, and exploring whether this affects consumers' willingness to buy
117 (WTB) and WTP. Regarding the type of information provided, given the effects that knowing
118 the composition of plant-based meat alternatives has on consumers, participants were
119 given information on the composition of the product they were going to eat under informed
120 conditions (e.g., whether the burger was made only of meat, partially with meat or only
121 with plant-based ingredients) with the aim to explore if such information had an effect on
122 consumers' liking, WTB and WTP.

123 This research provides useful insights for manufacturers of meat alternatives by providing
124 information about consumers' sensory evaluation of these products and their related
125 purchase likelihood (or WTB) and WTP, as well as for the academia as it helps enriching the
126 yet limited literature on consumers' attitude for meat alternatives.

127 2. Materials and methods

128 2.1. Products

129 All samples used were commercially available and consisted of a beef burger (Big Al's prime
130 beef burger: 99% beef, sea salt, smoked sea salt), a plant-based burger (Beyond burger:
131 water, pea protein isolate (16%), rapeseed oil, coconut oil, rice protein, flavouring, stabiliser
132 (methylcellulose), potato starch, apple extract, colour (beetroot red), maltodextrin,
133 pomegranate extract, salt, potassium chloride, concentrated lemon juice, maize vinegar,
134 carrot powder, emulsifier (sunflower lecithin) and a hybrid burger (Tesco Meat & Veg: 57%
135 beef, 38% vegetable blend of carrot and onion, rice flour, dried potato, salt, onion powder,
136 yeast extract, dextrose, black pepper, paprika, preservative (sodium metabisulphite),
137 sunflower oil, white pepper, emulsifier (mono- and di-glycerides of fatty acids), bay, black
138 pepper extract, onion oil).

139 2.2. Participants

140 A total of 99 UK consumers took part in this experiment. Consumers were included only if
141 they purchased and consumed beef burgers at least once every two months and if they
142 were fully or partially responsible for grocery shopping. Consumers were roughly balanced
143 for age (33 participants 18-24, 30 participants 35-54, 36 participants 55-75) and gender (44
144 males and 55 females). The study was conducted in the sensory laboratories of Wirral
145 Sensory Services, UK. All participants gave written informed consent and participated in the
146 blind and expected test in the same session, while the informed test took part the day after.
147 The study was granted ethical clearance by the School's Ethics committee (reference
148 number 1418D).

149 2.3. Evaluation procedure

150 The same participants evaluated the samples under all three different conditions:

151 Blind condition (with tasting and no information): consumers evaluated the three products
152 in a monadic sequence having received them in randomised order and with three-digit
153 random codes.

154 Expected condition (without tasting and with information): consumers were presented with
155 the main composition of the burgers to study the effect of composition information, though
156 they did not see or taste them. The beef, plant-based and hybrid were presented
157 respectively as "A burger made with 100% beef ", "A burger made with 100% plant-based
158 ingredients" "A burger made with 60 % beef and 40% vegetable blend (carrot and white
159 onion)". Using this information only, consumers were asked to evaluate the burgers in a
160 hypothetical way, based on their expectations.

161 Informed condition (with tasting and with information): consumers were asked to evaluate
162 the products while having corresponding information about the main composition of the
163 burger alongside it, to study the combined effect of sensory evaluation and composition
164 information.

165 Samples were cooked according to the manufacturers' instructions before being served hot
166 to participants. Each sample consisted of half a burger served on odourless white plastic
167 plates. Still mineral water and unsalted crackers were used to clean the palate between
168 samples. In the blind and informed conditions, consumers were asked to rate the overall
169 liking plus appearance, aroma and texture liking on a 9-point Likert scale going from
170 1=dislike extremely to 9=like extremely. In the expected condition, consumers were only
171 asked to express their expected overall liking for the three samples.

172 In the blind and informed conditions consumers were asked "How would you describe the
173 burger sample you just ate?". In the expected condition consumers were given the burger
174 description and asked "How would you expect this product to be?" After this, all conditions
175 were provided with twenty CATA terms presented in randomised orders. The CATA terms
176 used in this study were: dry, juicy, weak meat flavour, strong meat flavour, off flavour,
177 pleasant flavour, hard, soft, bland, tasty, cheap, expensive, unhealthy, healthy, processed,
178 unprocessed, characteristic, unusual, strong vegetable flavour, weak vegetable flavour.
179 These words were selected based on the frequently mentioned attributes emerged from the
180 literature on CATA for meat products (Grasso, Monahan, Hutchings, & Brunton, 2017;
181 Grasso, Smith, Bowers, Ajayi, & Swainson, 2019; Neville et al., 2017).

182 After the CATA questions, for all conditions consumers were asked for their WTB using a 1-7
183 scale going from 1=definitely would not buy to 7= definitely would buy. Consumers were
184 also asked for their WTP for the three burgers using the question "what is the maximum
185 price you would be willing to pay for a 2-burger packet of this burger?". In this way we were
186 able to explore WTP as an indicator of preference and evaluate whether WTP differed
187 across the conditions to determine if information had an effect. Although beef, plant-based
188 and hybrid burgers are commercially available and hence sale data are accessible, our study
189 provides additional information by measuring and comparing WTP under blind and
190 informed conditions which would not be obtainable otherwise in conventional retailer
191 settings. The multiple-price scale was curated by adapting the WTP methodology in similar
192 studies (Martin, Lange, & Marette, 2021). First, the average prices of beef, plant-based and
193 hybrid burgers available in supermarkets across the UK were sourced. This resulted in a
194 range of £1.8 to £2.6 which was then turned into a scale by marking increments of 20p
195 (£1.6, £1.8, £2, £2.2, £2.4, £2.6 and £2.8). The question on WTB also included an opt-out
196 option, in case consumers were not willing to pay for the product at all.

197 After, under blind and informed conditions, consumers were asked to answer two open
198 questions, describing in their own words what they liked and what they disliked about each
199 product. Answering these was not mandatory, therefore in this way they could express only
200 likes, only dislikes, both, and none for each sample. Finally, at the end of the informed
201 session, consumers were asked to rank the burger samples from 1=most to 3=least for the
202 adjectives tasty, healthy, nutritious, environmentally-friendly and quality.

2.4. Text analysis

203
204 Free comments were standardised for further analysis. The terms were transformed into
205 more structured terms according to the following criteria: (a) verifying typing and spelling

206 and correcting grammatical errors; (b) removing connectors and auxiliary terms when a
 207 consumer wrote a sentence instead of separate terms; (c) hedonic terms (good, nice) were
 208 removed since the questions already considered separately likes and dislikes; (d) some
 209 terms such as synonymous or derivatives of the same term were regrouped considering the
 210 initial complete full statement. This process was based on the textual analysis detailed in
 211 Ares, Giménez, Barreiro, and Gámbaro (2010); Symoneaux, Galmarini, and Mehinagic
 212 (2012); ten Kleij and Musters (2003).

213 Then, likes and dislikes were re-transcribed into simple modalities of (L_) for likes and (D_)
 214 for dislikes for each consumer and each product crossed with condition (e.g. beef blind, beef
 215 informed). Once the re-transcription of the 99 consumers for the three products under both
 216 conditions was done, simplified comments per product were counted. Only the descriptors
 217 mentioned by at least 5% of consumers for at least one product under blind or informed
 218 condition were used. For an example of the text analysis process, see Table 1.

219 Table 1. Example of the transformation of free comments for likes and dislikes given by
 220 consumers for products crossed with condition (e.g. beef blind), into simplified and
 221 structured comments (L_ for likes and D_ for dislikes).

Subject	Product/Condition	Raw comment	Simplified comment
16	Beef blind	"I liked how juicy the burger was and the overall flavour"	L_juicy; L_flavour
1	Beef informed	"meat flavour and aroma is very appealing, nice level of moistness appearance is average"	L_meaty; L_taste; L_aroma; L_moist; L_appearance
69	Plant blind	"I enjoyed the colour, taste & texture of this burger. very juicy"	L_colour; L_taste; L_texture; L_juicy
19	Plant informed	"nice moistness to it, fairly good taste to it"	L_moist; L_taste
28	Hybrid blind	"the burger was very juicy and soft. it also had a nice taste"	L_juicy; L_soft; L_taste
19	Hybrid informed	"good strength of flavour, nice chew to it, like the aftertaste, nice and moist, good feel in the mouth when chewing"	L_flavour; L_chewiness; L_aftertaste; L_moist; L_mouthfeel/texture
31	Beef blind	"the burger was too chewy, quite hard and the strength of flavour was too mild"	D_chewy; D_hard; D_bland
94	Beef informed	"it is too chewy meat flavour is not strong enough"	D_chewy; D_weak meat; D_flavour

29	Plant blind	“overall look of burger was not very appealing. texture in mouth was very bitty”	D_appearance; D_texture; D_bitty
28	Plant informed	“I don't like the texture of the burger, I feel that its too rubbery”	D_texture; D_rubbery
30	Hybrid blind	“was too soft and tasted awful”	D_soft; D_taste
12	Hybrid informed	“maybe a bit dry”	D_dry

2.5. Data analysis

ANOVA (F-test statistic) was performed within the blind, expected and informed conditions for liking, WTB and WTP. Repeated measured ANOVA was carried out across three conditions and for the three samples. When a difference was found, paired sample T-tests were carried out to understand between which pairs the differences were. For the CATA and text analysis data, the frequency of each term was counted and a contingency table was produced. Cochran's Q tests were carried out using the test statistic reported by Meyners and Castura (2014), followed by McNemar tests with a Bonferroni correction as a post-hoc test if a difference was found among the three samples. The ranking data was analysed using a Friedman's test. Correspondence analysis was applied to the CATA and text analysis in order to visualise the relationship between samples and CATA terms or comments. Statistical analyses were performed using Microsoft Excel for Office 365 (Microsoft Co.), SPSS (version 27) statistical software (IBM Inc. Chicago, IL, USA), and XLSTAT (XLSTAT version 2020.4.1, Addinsoft). A p-value of 0.05 was used as the threshold for significance.

3. Results and Discussion

3.1. Liking

Significant differences were found in consumers' overall acceptability of the three burgers under blind, expected and informed conditions (Table 2). All products used in this study were commercially available in the UK market, but in the blind condition only the hybrid burger emerged as a liked product (mean liking score > 6 = liked slightly).

Within the blind condition the hybrid burger scored significantly higher than beef and plant-based burgers for overall liking and the beef burger scored significantly higher than the plant-based one.

In the expected condition, consumers expected to overall like beef burgers significantly more than plant-based and hybrid burgers, with no difference in the expected overall liking between plant-based and hybrid burgers.

As for the informed condition, consumers overall liked most the hybrid burger and least the plant-based burger, while the beef burger had an intermediate score, not significantly different from the hybrid or the plant-based burger. The overall liking of beef and plant-

252 based burgers significantly changed among the three conditions, while no significant
 253 changes were detected for the hybrid burger.

254 Significant negative disconfirmation occurred for the beef and plant-based samples, because
 255 the blind liking differed significantly from the expected liking (consumers had higher
 256 expectations than sensory blind acceptance). Tasting with information had a significant
 257 effect on overall liking of the beef and plant-based samples, as shown by the significant I-B
 258 scores. An assimilation effect ($((I-B)/(E-B) > 0)$) was identified for the three products. This
 259 means higher informed than blind acceptability scores, therefore information provided to
 260 consumers improved the product's acceptability. For the hybrid burger there was a
 261 complete assimilation because the informed and expected liking scores did not differ
 262 significantly, denoting a complete fulfilment of hedonic expectations for this product. While
 263 for the plant-based and beef samples the assimilation was incomplete (the informed score
 264 was lower than the expected score), indicating that consumers' expectations that were
 265 aroused by the composition information were not fully satisfied. Information had a
 266 significant effect on consumer liking also in the study by Schouteten et al. (2016) who
 267 compared insect, plant and meat-based burgers, finding complete assimilation for the
 268 insect-based burger.

269 Table 2. Overall acceptability for the three burgers in the blind (B), expected (E) and
 270 informed (I) conditions, together with differences between mean ratings.

Sample	Blind	Expected	Informed	E-B	I-B	I-E
Beef	5.77 ^b	8.19 ^a	6.44 ^{ab}	2.41 ^{***} negative disconfirmation	0.68 ^{***} assimilation	-1.74 ^{***} incomplete assimilation
Plant- based	4.74 ^c	6.70 ^b	5.89 ^b	1.98 ^{***} negative disconfirmation	1.15 ^{***} assimilation	-0.83 ^{***} incomplete assimilation
Hybrid	6.69 ^a	6.84 ^b	6.99 ^a	0.14 negative disconfirmation	0.30 assimilation	0.16 complete assimilation

271 ^{a,b,c} Within the same condition, products with different letters, within-in a column, are
 272 significantly different ($p \leq 0.05$ – repeated measures ANOVA and pairwise comparisons)
 273 during the condition (blind/expected/informed). *** depicts significant differences between
 274 the liking scores at $p \leq 0.001$.

275 Table 3 shows appearance, aroma, texture, and taste liking for the three burger samples in
 276 the blind and informed conditions. In the blind condition, for appearance, beef burgers
 277 scored highest, plant-based samples scored lowest and hybrid samples were in the middle
 278 and not significantly different from beef and plant-based samples. For aroma liking, the
 279 hybrid burger scored significantly higher than beef and plant-based samples. For the
 280 attributes of texture and taste liking, hybrid and beef samples scored similarly and
 281 significantly higher than plant-based burgers.

282 In the informed condition, for appearance there was no significant difference among the
 283 three samples. For aroma liking, the hybrid still scored significantly higher than beef and
 284 plant-based samples. In terms of texture, both hybrid and beef burgers still scored similarly

285 and higher than plant-based burgers. Finally, hybrid burgers scored highest for taste liking,
 286 plant-based burgers scored lowest and beef burgers scored between the two, but they were
 287 not significantly different from either of them.

288 Moving from the blind to the informed condition, the liking of all attributes for all burger
 289 samples significantly increased, except for appearance of the beef burgers and taste of the
 290 hybrid burgers.

291 Table 3. Appearance, aroma, texture and taste liking for the three burger samples in the
 292 blind and informed conditions.

Sample	Appearance		Aroma		Texture		Taste	
	Blind	Informed	Blind	Informed	Blind	Informed	Blind	Informed
Beef	6.39 ^{ax}	6.43 ^{ax}	5.77 ^{by}	6.28 ^{bx}	5.69 ^{ay}	6.58 ^{ax}	6.03 ^{ay}	6.53 ^{abx}
Plant-based	5.74 ^{by}	6.47 ^{ax}	5.40 ^{by}	5.94 ^{bx}	4.71 ^{by}	5.65 ^{bx}	4.90 ^{by}	6.14 ^{bx}
Hybrid	6.23 ^{aby}	6.68 ^{ax}	6.70 ^{ay}	7.34 ^{ax}	6.40 ^{ay}	7.16 ^{ax}	6.74 ^{ax}	6.99 ^{ax}

293 ^{a,b,c} Within the same condition, products with different letters, within in a column, are
 294 significantly different (p ≤ 0.05– ANOVA and Tukey’s test) during the same condition
 295 (blind/informed). ^{x,y,z} Between conditions, products with different letters, within in a row,
 296 are significantly different (p ≤ 0.05–paired sample T-test) between the blind and informed
 297 conditions.

298 Purchase intent for the three burgers under the three conditions is shown in table 4.
 299 Purchase intent within the blind condition shows that consumers were most willing to buy
 300 hybrid burgers, followed by beef burgers and least willing to buy plant-based burgers. In the
 301 expected condition, beef burgers scored higher for WTB than both hybrid and plant-based
 302 samples. In the informed condition, purchase intent was again higher for hybrid burgers
 303 compared to plant-based burgers. Beef burgers scored between hybrid and plant-based
 304 burgers, and they were not significantly different from either of them.

305 Purchase intent significantly changed across the blind, expected, and informed conditions
 306 for beef and plant-based burgers, but not for hybrid burgers. Indeed, for beef and plant-
 307 based burgers purchase intent was highest in the expected condition, lowest in the blind
 308 condition and intermediate in the informed condition.

309 Table 4. Purchase intent for the three burgers in the blind, expected and informed
 310 conditions.

Sample	Purchase intent		
	Blind	Expected	Informed
Beef	3.93 ^{bz}	6.23 ^{ax}	4.45 ^{aby}
Plant-based	3.07 ^{cz}	4.93 ^{bx}	4.22 ^{cy}

Hybrid 4.74^{ax} 5.09^{bx} 4.95^{ax}

a,b,c Products with different letters, within a column, are significantly different ($p \leq 0.05$ —ANOVA and Tukey’s test) within the same condition (blind/expected/informed). ^{x,y,z} Products with different letters, within a row, are significantly different ($p \leq 0.05$) across the blind, expected and informed conditions.

The results of main and interaction effects as well as the contrasts of two-way repeated measures ANOVA are displayed in Table 5. Mauchly’s test indicated that the assumption of sphericity has been violated for the interaction effect of sample and condition, $\chi^2(9) = 24.94, p = 0.003$. Therefore, degree of freedom is corrected using Greenhouse – Geisser estimate of sphericity. It is found that there is a significant main effect of type of burgers on WTP, $F(2,196) = 17.97, p \leq 0.001$. Contrasts reveals that WTP for plant-based burger is significantly lower (Table 6) than beef burger, $F(1,98) = 30.59, p \leq 0.001$, whereas WTP for hybrid burger is lower than beef burger, but not significant ($F(1,98) = 1.54, p = 0.218$).

There is also significant main effect of different conditions on WTP, $F(2,196) = 83.29, p \leq 0.001$. Contrasts reveals that WTP for informed condition, $F(1,98) = 33.63, p \leq 0.001$ and expected condition, $F(1,98) = 175.26, p \leq 0.001$ are significantly higher than blind condition.

There is a significant interaction effect between the type of burgers and the conditions used, $F(3.56,348.20) = 83.29, p \leq 0.001$. This indicates that condition has different effect on participant’s WTP depending on which type of burger is used. Contrasts are performed comparing all sample types to their baseline (beef burger) and all condition types to their baseline (blind condition) which reveals significant interactions when comparing expected condition to blind condition both for plant-based burger compared to beef burger, $F(1,98) = 4.57, p = 0.035$, and hybrid burger compared to beef burger, $F(1,98) = 50.17, p \leq 0.001$.

Table 5. Results of Two-way repeated measures ANOVA

Source		df	F	Sig.
Product	Sphericity Assumed	2	17.965	.001
Error(Product)	Sphericity Assumed	196		
Condition	Sphericity Assumed	2	83.293	.001
Error(Condition)	Sphericity Assumed	196		
	Greenhouse-Geisser	3.553	17.178	.001
	Greenhouse-Geisser	348.196		
	Sample	Condition		
Sample	Plant-based vs. Beef	1	30.592	.001
	Hybrid vs. Beef	1	1.537	.218
Condition	Informed vs. Blind	1	33.625	.001
	Expected vs. Blind	1	175.257	.001

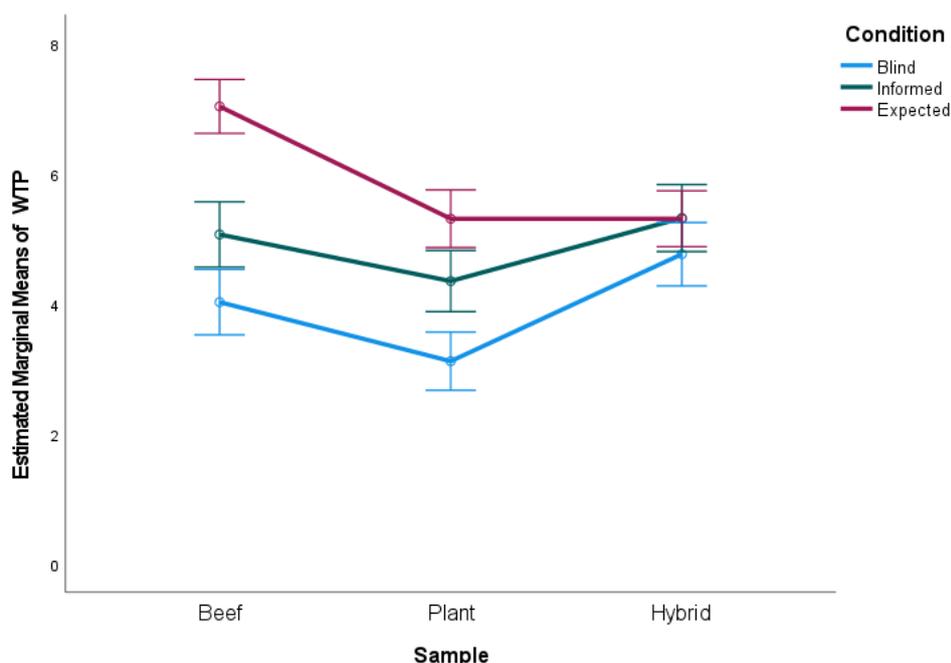
<u>Sample *</u>	<u>Plant-based</u>	<u>Informed vs. Blind</u>	<u>1</u>	<u>.346</u>	<u>.557</u>
<u>Condition</u>	<u>vs. Beef</u>	<u>Expected vs. Blind</u>	<u>1</u>	<u>4.571</u>	<u>.035</u>
	<u>Hybrid vs.</u>	<u>Informed vs. Blind</u>	<u>1</u>	<u>2.297</u>	<u>.133</u>
	<u>Beef</u>	<u>Expected vs. Blind</u>	<u>1</u>	<u>50.173</u>	<u>.001</u>

In the blind condition the WTP was similar for beef and hybrid burgers, but it was significantly lower in plant-based burgers. In the expected condition, consumers were willing to pay significantly more for beef burgers compared to hybrid and plant-based burgers. Finally, in the informed condition, the maximum WTP was similar for beef and hybrid burgers but lower for plant-based burgers showing the same trend seen in the blind condition.

Table 6. Maximum WTP for the three burgers in the blind, expected and informed conditions.

Maximum WTP							
Main effect				Interaction effect			
Sample		Condition		Sample*Condition			
				Blind	Expected	Informed	
Beef	5.37	Blind	3.96	Beef	4.02	7.03	5.06
Plant-based	4.25	Expected	5.88	Plant-based	3.11	5.30	4.34
Hybrid	5.13	Informed	4.91	Hybrid	4.76	5.30	5.31

The maximum WTP for beef and plant-based burgers followed a similar trend across conditions as the purchase intent, as the maximum WTP was highest in the expected condition, lowest in the blind condition and intermediate in the informed condition. For the hybrid burgers, the maximum WTP was similar in the expected and informed conditions, while it was significantly lower in the blind condition. (Figure 1)



352 [Figure 1. Mean variation of different burgers under different conditions. Error bars are plus](#)
353 [or minus two standard errors.](#)

354 [Information therefore had a significant effect on both purchase intent and WTP for the](#)
355 [three burgers in this study. This is in accordance with Martin et al. \(2021\) who reported a](#)
356 [positive effect of different types of information on the acceptability of plant-based](#)
357 [sausages.](#)

3.2. Check-all-that-apply

360 The contingency table (Table 5) summarises the frequency of use for each CATA term by
361 assessors. Cochran's Q test showed significant differences in the frequency of the majority
362 of the attributes used to describe the burger samples.

363 Within the blind condition, only the attributes "expensive", "processed" and "unprocessed"
364 did not discriminate among the three burgers. Both beef and plant-based burgers were
365 more often associated to "dry" and "hard" than hybrid burgers. The opposite terms "juicy"
366 and "soft" also reflected this difference, with hybrid burgers being associated to this word
367 more than beef and plant-based burgers. Consumers also associated hybrid burgers to
368 "strong vegetable flavour" and "healthy" more than to beef and plant-based ones. For
369 "unhealthy", beef burgers scored highest, hybrid scored lowest and plant-based scored in
370 between and not differently from the other two burgers. For the attributes "weak meat
371 flavour", "off-flavour", "cheap" and "weak vegetable flavour", plant-based burgers scored
372 highest, hybrid burgers scored lowest, while beef samples scored in between and not
373 differently from the other two burgers. In the blind condition beef burgers scored higher
374 than the other two burgers for the attribute "strong meat flavour". Hybrid burgers scored
375 highest for "pleasant flavour", "tasty" and "characteristic", while plant-based burgers scored
376 lowest and beef burgers scored in between and not differently from the other two burgers.
377 Plant-based burgers scored significantly higher than the other two burgers for "bland" and
378 "unusual".

379 In the expected condition, the attributes "pleasant flavour", "hard", "cheap" and
380 "characteristic" did not discriminate among the three burgers. For the attributes "weak
381 meat flavour", "off-flavour", "soft", "healthy", "processed" and "unusual", plant-based and
382 hybrid samples scored similarly and significantly higher than beef burgers. Beef burgers
383 were most often associated to "juicy", "strong meat flavour", "tasty", while plant-based
384 burgers were the least associated and hybrid samples were in between. Plant-based burgers
385 were more often associated to "dry" and "bland" than beef and hybrid burgers. Beef
386 burgers were associated to "expensive" and "unhealthy" more often than plant-based and
387 hybrid burgers. Finally, the beef and plant-based burgers were significantly more often
388 associated with the term "unprocessed" than the hybrid burgers.

389 In the informed condition, seven attributes did not discriminate among burger samples:
390 "weak meat flavour", "off-flavour", "pleasant flavour", "expensive", "unhealthy",
391 "unprocessed" and "characteristic". The attributes "dry" and "hard" discriminated nicely the

three burgers, with beef scoring highest, plant-based burgers scoring in-between and hybrid samples scoring lowest. The opposite trend can be seen for the attribute “soft”. The hybrid burgers were the least associated to “bland”, while beef and plant-based were the most associated to this term. For “tasty” hybrid scored highest and plant-based burgers lowest, while beef burgers scored in the middle and not differently from the other two burgers. Hybrid burgers were most often associated to “juicy” and “strong vegetable flavour”, followed by plant-based and beef burgers. Plant-based burgers scored highest for “weak vegetable flavour”, followed by hybrid and beef burgers. Beef burgers scored highest for “strong meat flavour”, “cheap” and “processed” and lowest for “healthy” and “unusual”.

It is interesting to note that there are some common themes running across the blind, expected and informed conditions. For example, the attribute “strong meat flavour” is consistently more often associated to beef burgers than the other samples. However other attributes, such as “juicy” and “dry” changed among conditions. For example, in the blind condition the hybrid burgers were more often associated to “juicy” and “soft”, while beef and plant-based burgers were more often associated to “dry” and “hard”. In the expected condition, consumers associated beef burgers to “juicy” and plant-based to “dry”. Finally, in the informed condition, beef samples were again associated to “dry” and “hard”, while hybrid samples were associated to “juicy” and “soft”.

Table 75. Frequency and proportions of CATA terms selected by consumers for the three burgers in the three conditions.

Attribute	Blind			Expected			Informed		
	Beef	Plant	Hybrid	Beef	Plant	Hybrid	Beef	Plant	Hybrid
Dry	20(4.8) ^a	17(4.0) ^a	1(0.2) ^b	1(0.2) ^b	20(4.0) ^a	4(0.8) ^b	46(10.3) ^a	21(4.3) ^b	5(1.0) ^c
Juicy	49(11.8) ^b	35(8.1) ^b	77(15.9) ^a	91(17.8) ^a	41(8.2) ^c	60(12.1) ^b	41(9.2) ^b	47(9.6) ^b	68(13.3) ^a
Weak meat flavour	26(6.3) ^{ab}	39(9.1) ^a	22(4.5) ^b	0(0.0) ^b	32(6.4) ^a	21(4.3) ^a	17(3.8) ^{ns}	31(6.3) ^{ns}	17(3.3) ^{ns}
Strong meat flavour	44(10.6) ^a	16(3.7) ^b	23(4.7) ^b	89(17.4) ^a	7(1.4) ^c	33(6.7) ^b	61(13.6) ^a	15(3.1) ^c	33(6.5) ^b
Off-flavour	17(4.1) ^{ab}	26(6.0) ^a	6(1.2) ^b	0(0.0) ^b	7(1.4) ^a	7(1.4) ^a	9(2.0) ^{ns}	16(3.3) ^{ns}	12(2.4) ^{ns}
Pleasant flavour	37(8.9) ^{ab}	23(5.3) ^b	52(10.7) ^a	62(12.1) ^{ns}	47(9.3) ^{ns}	54(10.9) ^{ns}	37(8.3) ^{ns}	39(8.0) ^{ns}	54(10.6) ^{ns}
Hard	24(5.8) ^a	16(3.7) ^a	1(0.2) ^b	3(0.6) ^{ns}	6(1.2) ^{ns}	5(1.0) ^{ns}	26(5.8) ^a	10(2.0) ^b	0(0.0) ^c
Soft	10(2.4) ^c	24(5.6) ^b	66(13.6) ^a	20(3.9) ^b	36(7.2) ^a	42(8.5) ^a	21(4.7) ^c	41(8.4) ^b	63(12.4) ^a
Bland	18(4.3) ^b	36(8.4) ^a	7(1.4) ^b	2(0.4) ^b	21(4.2) ^a	7(1.4) ^b	20(4.5) ^a	18(3.7) ^a	4(0.8) ^b
Tasty	38(9.2) ^{ab}	22(5.1) ^b	53(10.9) ^a	90(17.6) ^a	39(7.8) ^c	60(12.1) ^b	50(11.2) ^{ab}	40(8.2) ^b	64(12.5) ^a
Cheap	23(5.5) ^{ab}	31(7.2) ^a	13(2.7) ^b	1(0.2) ^{ns}	2(0.4) ^{ns}	7(1.4) ^{ns}	29(6.5) ^a	14(2.9) ^b	8(1.6) ^b
Expensive	8(1.9) ^{ns}	4(0.9) ^{ns}	11(2.3) ^{ns}	50(9.8) ^a	27(5.4) ^b	16(3.2) ^b	11(2.5) ^{ns}	10(2.0) ^{ns}	10(2.0) ^{ns}
Unhealthy	15(3.6) ^a	14(3.3) ^{ab}	4(0.8) ^b	13(2.5) ^a	1(0.2) ^b	3(0.6) ^b	12(2.7) ^{ns}	3(0.6) ^{ns}	3(0.6) ^{ns}
Healthy	7(1.7) ^b	17(4.0) ^b	39(8.0) ^a	25(4.9) ^b	68(13.5) ^a	54(10.9) ^a	9(2.0) ^b	46(9.4) ^a	37(7.3) ^a
Processed	33(8.0) ^{ns}	33(7.7) ^{ns}	19(3.9) ^{ns}	5(1.0) ^b	25(5.0) ^a	20(4.0) ^a	29(6.5) ^a	26(5.3) ^{ab}	13(2.5) ^b
Unprocessed	4(1.0) ^{ns}	2(0.5) ^{ns}	8(1.6) ^{ns}	27(5.3) ^a	18(3.6) ^a	7(1.4) ^b	7(1.6) ^{ns}	5(1.0) ^{ns}	8(1.6) ^{ns}
Characteristic	7(1.7) ^{ab}	3(0.7) ^b	14(2.9) ^a	21(4.1) ^{ns}	12(2.4) ^{ns}	11(2.2) ^{ns}	7(1.6) ^{ns}	12(2.4) ^{ns}	16(3.1) ^{ns}
Unusual	25(6.0) ^b	46(10.7) ^a	26(5.4) ^b	1(0.2) ^b	27(5.4) ^a	31(6.3) ^a	7(1.6) ^c	50(10.2) ^a	33(6.5) ^b
Strong vegetable flavour	3(0.7) ^b	8(1.9) ^b	38(7.8) ^a	1(0.2) ^c	64(12.7) ^a	37(7.5) ^b	0(0.0) ^c	27(5.5) ^b	57(11.2) ^a
Weak vegetable flavour	7(1.7) ^{ab}	18(4.2) ^a	5(1.0) ^b	10(2.0) ^{ab}	3(0.6) ^b	15(3.0) ^a	8(1.8) ^b	19(3.9) ^a	5(1.0) ^b
total	415	430	485	512	503	494	447	490	510

412 a,b,c Within the same condition, attributes with different letters in a row, within the same
413 blind/expected or informed condition in a row, are significantly different ($p \leq 0.05$ -
414 Cochran's Q test). The proportions relative to the total are in brackets.

415 3.3. Correspondence analysis

416 Figure 1 shows the burger samples and CATA terms in the first two coordinates of the
417 correspondence analysis (CA) for the three conditions. Overall, the first and second
418 dimensions combined explained 100% of the variance in the data, with a strong first
419 dimension (78.1-87.7%) and a less important second dimension (12.3-21.9%).

420 In the blind condition, the first dimension was positively correlated with the terms "strong
421 vegetable flavour", "soft" and "healthy" and negatively correlated with the terms "hard",
422 "dry", "unhealthy", "off-flavour" and "bland". The second dimension was positively
423 correlated with the term "strong meat flavour" and negatively correlated with "weak
424 vegetable flavour".

425 In the expected condition, the first dimension was positively correlated with the terms
426 "strong meat flavour" and "unhealthy" and negatively correlated with the opposite terms
427 "weak meat flavour", "healthy", as well as "bland" and "dry". The second dimension was
428 positively correlated with the term "cheap" and negatively correlated with "dry".

429 In the informed condition, the first dimension was positively correlated with the term
430 "strong vegetable flavour" and negatively correlated with the term "hard". The second
431 dimension was positively correlated with the term "weak vegetable flavour" and negatively
432 correlated with "strong meat flavour".

433 The properties of the three burger groups were well separated in the three conditions. In
434 the blind condition, hybrid burgers were located at positive values of the first dimension,
435 while beef burgers were at positive values of the second dimension and plant-based burgers
436 were at negative values of both first and second dimension. In the expected condition there
437 is a change in the location of hybrid and beef burgers, with beef burgers located at positive
438 values of the first dimension and hybrid burgers at positive values of the second dimension
439 (no change for plant-based burger). Finally, in the informed condition, there is another
440 change, with both plant-based and hybrid burgers located at positive values of the first
441 dimension and beef samples at negative values of both first and second dimension (where
442 plant-based burgers were found in the previous conditions).

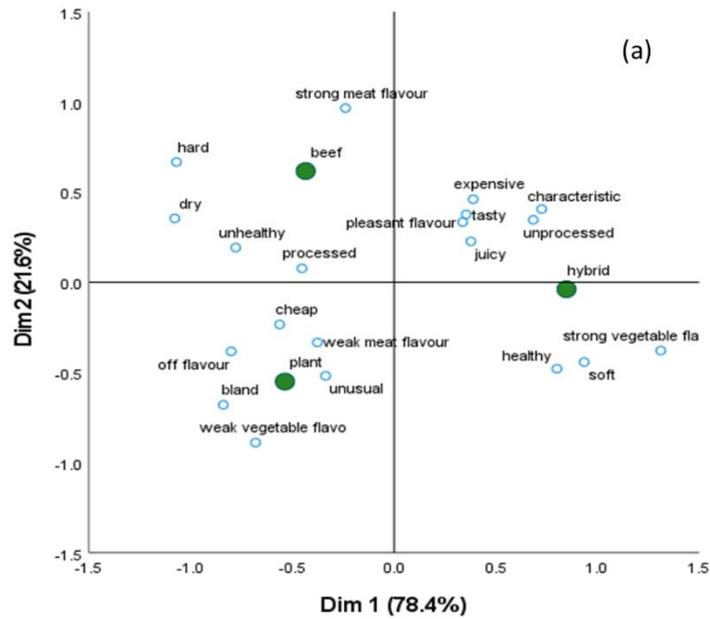
443 In the blind condition, consumers associated plant-based burgers with "unusual", "weak
444 meat flavour", "bland", "off-flavour" and "cheap", beef burgers with "strong meat flavour",
445 "hard", "dry", "unhealthy" and "processed", and hybrid burgers with "soft", "healthy",
446 "juicy" and "unprocessed".

447 In the expected condition, consumers associated plant-based burgers with "weak meat
448 flavour", "bland" and "strong vegetable flavour", beef burgers with "unhealthy", "strong
449 meat flavour" and "juicy", and hybrid burgers with "soft", "unusual" and "off-flavour".

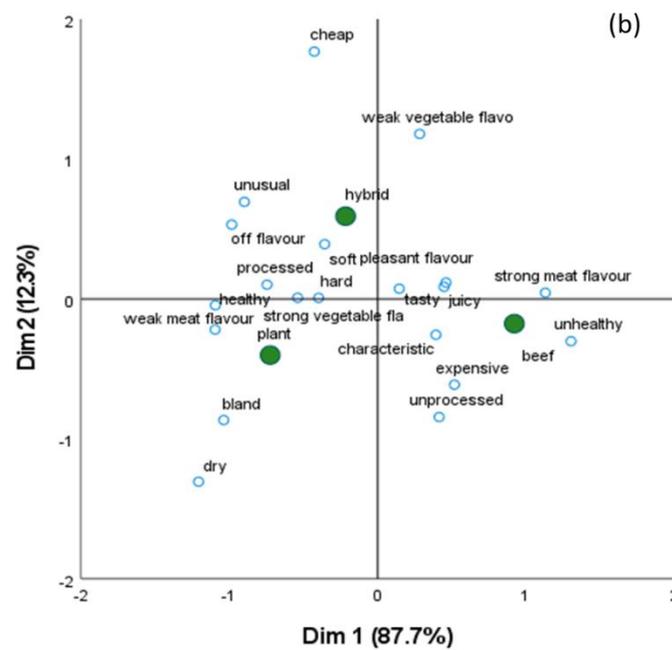
450 In the informed condition, consumers associated plant-based burgers with “weak meat
 451 flavour”, “off-flavour”, “healthy” and “unusual”, beef burgers with “cheap”, “dry” and
 452 “unhealthy” and finally hybrid burgers with “soft”, “juicy” and “strong vegetable flavour”.

453 Regardless of the information, in our study the three burger samples were sorted into three
 454 distinctive areas according to their sensory attributes in the CA plot. In contrast, Neville et
 455 al. (2017) found that meat burgers were in the same area as the hybrid burgers in their CA
 456 plot. These differences are probably due to the different recipes used in the studies.

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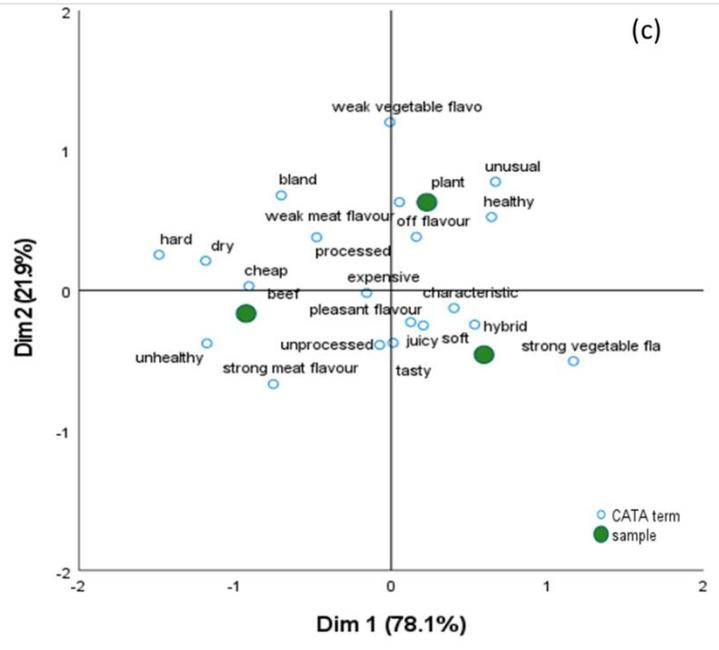


Figure 24. CATA terms used to describe the beef, plant-based and hybrid burgers in the first two dimensions of the CA-Correspondance analysis performed using the CATA data with χ^2 -distances. (a) blind condition, (b) expected condition, (c) informed condition.

3.4. Penalty-lift analysis

Table 6 shows the results of the penalty-lift analysis, estimating how much liking changed when an attribute was selected by a consumer compared to when it was not selected. In this study it was interesting to investigate how providing information on the burgers impacted the drivers of like and dislike across conditions. For ease, only the top three and bottom three drivers are reported in Table 6.

Table 86. Penalty-lift analysis for the three burgers in the three conditions. The values indicate a change in liking when an attribute was ticked compared to when it was not ticked by consumers.

	Blind	Liking change	Expected	Liking change	Informed	Liking change
Beef (top 3)	Tasty	3.45	Strong vegetable flavour	0.82	Tasty	2.58
	Pleasant flavour	2.96	Juicy	0.62	Pleasant flavour	2.05
	Strong meat flavour	2.83	Unprocessed	0.45	Strong meat flavour	1.79
Beef (bottom 3)	Off-flavour	-3.27	Unusual	-3.22	Bland	-2.44
	Bland	-3.18	Cheap	-1.20	Off-flavour	-2.32
	Weak vegetable flavour	-2.98	Bland	-0.70	Unusual	-2.17

Plant-based (top 3)	Expensive	3.40	Tasty	1.90	Tasty	2.62
	Tasty	3.20	Pleasant flavour	1.67	Pleasant flavour	2.47
	Healthy	2.94	Strong meat flavour	1.25	Expensive	2.46
Plant-based (bottom 3)	Unhealthy	-3.02	Bland	-1.91	Cheap	-4.11
	Off-flavour	-2.30	Off-flavour	-1.67	Off-flavour	-3.59
	Cheap	-2.29	Dry	-1.56	Unhealthy	-3.32
Hybrid (top 3)	Tasty	2.42	Tasty	1.72	Tasty	3.08
	Pleasant flavour	2.40	Pleasant flavour	1.58	Pleasant flavour	2.22
	Juicy	1.82	Juicy	1.38	Juicy	2.10
Hybrid (bottom 3)	Off-flavour	-3.22	Off-flavour	-2.90	Off-flavour	-3.50
	Bland	-2.44	Cheap	-2.44	Cheap	-2.16
	Cheap	-2.21	Dry	-1.66	Bland	-2.07

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The main drivers for hybrid burger liking did not change with information on burger composition and were consistently “tasty”, “pleasant flavour” and “juicy” across conditions. The drivers of dislike for hybrid burgers were the same in both blind and informed conditions (“off-flavour”, “bland” and “cheap”) and only one driver was different in the expected condition (“dry” instead of “bland”).

In beef burgers the main drivers for liking did not change in the blind and informed conditions and were always “tasty”, “pleasant flavour” and “strong meat flavour”, while in the expected condition they changed to “strong vegetable flavour”, “juicy” and “unprocessed”. The word “bland” was a main driver for dislike in the three conditions, “off-flavour” was common in both the blind and informed conditions, while “unusual” was common between the expected and informed conditions.

For the plant-based burgers, “tasty” was a common driver for liking across all conditions, “expensive” was in common between the blind and informed conditions and “pleasant flavour” between the expected and informed conditions. The main drivers for dislike did not change between the blind and informed conditions (“unhealthy”, “off-flavour” and “cheap”), while in the expected condition they were “bland”, “off-flavour” and “dry”.

3.5. Ranking

Analysis of the ranking data is reported in Table 7. There was no significant difference among the three burger samples for the attributes “tasty” and “quality”. For the attributes “healthy” and “nutritious” plant-based and hybrid burgers scored similarly and significantly higher than beef burgers. The attribute “environmentally-friendly” was the only one that significantly discriminated among the three burgers, with plant-based burgers scoring highest, followed by hybrid burgers and beef burgers scored last.

497 Table 97. Consumer ranking of beef, plant based and hybrid burgers according to five
 498 adjectives, from most (1) to least (3).

Attribute	Beef	Plant	Hybrid
Tasty ^{ns}	2.01	2.16	1.83
Healthy	2.49 ^b	1.74 ^a	1.77 ^a
Nutritious	2.41 ^b	1.94 ^a	1.65 ^a
Environmentally-friendly	2.68 ^c	1.40 ^a	1.92 ^b
Quality ^{ns}	2.02	2.16	1.82

499 ^{a,b,c} Attributes with different letters, within a row, are significantly different ($p \leq 0.05$;
 500 [Friedman's test](#)) among the three burger samples.

501 3.6 Text analysis

502 3.6.1 Contingency table

503 Table 8 shows the terms given in the comments for each sample and the percentage of
 504 mentions for each term within the total for that category (like or dislike). Comments that
 505 appeared with a lower frequency than 5% per sample-condition were excluded from the
 506 analysis.

507 The most recurrent likes (L) mentioned by consumers were “taste”, “juiciness”,
 508 “appearance”, and “texture”. On the other hand, the principally mentioned dislikes (D) were
 509 “taste”, “texture”, “chewiness”, and “blandness”. Cochran's Q test showed significant
 510 differences in the frequency of some attributes that consumers used to describe the
 511 samples.

512 Under blind conditions, consumers commented liking the “taste” and “moistness” of hybrid
 513 samples more often than plant-based samples, while beef samples scored in the middle and
 514 were not different from the other two samples. Both beef and plant-based burgers were
 515 more often associated to “D_chewy” than hybrid burgers. Only the hybrid burger was
 516 associated with “vegetable flavour”, however this was both reported in a positive (like) and
 517 negative (dislike) way by consumers.

518 Under informed conditions, unsurprisingly beef samples were the most commented as
 519 “L_meaty” compared to plant and hybrid samples. Consumers disliked more the “texture” of
 520 plant-based burgers than hybrid and beef burgers. Consumers also disliked more frequently
 521 the “dryness” and “chewiness” of the beef burger compared to the other samples. Beef was
 522 the only sample not commented as “L_healthy”.

523 3.6.2 Comparison of comments with overall liking

524 Comparing overall liking with the number of comments, the hybrid informed sample had the
 525 highest overall liking (hedonic=6.99), the second highest number of like comments (210)
 526 and the least number of dislikes (98); followed by the hybrid blind sample, which had the
 527 second-best overall liking (hedonic=6.69), the most like comments (214) and the second
 528 least number of dislike comments (110); the least liked sample was plant-based blind
 529 (hedonic =4.74) which had more dislikes comments (168) than like comments (129). The
 530 other samples – beef informed, beef blind, and plant-based informed – with intermediate

531 scores, received a similar number of likes and dislikes. Therefore, we found that the higher
 532 the ratings are given for a product, the more comments consumers gave for likes and the
 533 less they gave for dislikes; and lower ratings were related to more dislike than like
 534 comments similarly to previous findings by Symoneaux et al. (2012).

535 Table 108. Like (L) and dislike (D) comments for each sample in blind and informed
 536 conditions. Number of mentions, proportion of each (%) and total mentions per sample
 537 crossed with condition.

Comments	Blind			Informed			%*
	Beef	Plant	Hybrid	Beef	Plant	Hybrid	
<i>Like comments (L)</i>							
Taste	46 ^{ab}	29 ^b	57 ^a	54 ^{ab}	46 ^b	64 ^a	27.8
Juicy ^{ns}	24	14	25	16	13	31	11.6
Appearance ^{ns}	18	18	23	13	13	14	9.3
Texture ^{ns}	15	10	12	14	13	18	7.7
Meaty	16 ^{ns}	5 ^{ns}	6 ^{ns}	24 ^a	7 ^b	10 ^b	6.4
Aroma	9 ^{ns}	5 ^{ns}	7 ^{ns}	11 ^{ab}	6 ^b	16 ^a	5.1
Aftertaste ^{ns}	7	6	12	7	11	6	4.6
Colour ^{ns}	10	9	5	7	6	7	4.1
Soft	4 ^b	4 ^{ab}	14 ^a	5 ^{ns}	6 ^{ns}	9 ^{ns}	4.0
Moist	4 ^{ab}	2 ^b	10 ^a	4 ^{ns}	8 ^{ns}	7 ^{ns}	3.3
Thickness ^{ns}	3	10	9	1	6	4	3.1
Seasoning ^{ns}	1	1	9	3	3	4	2.0
Chewy enough ^{ns}	5	2	4	4	2	2	1.8
Size ^{ns}	1	5	5	4	3	0	1.7
Veg (taste)	0 ^b	0 ^b	9 ^a	0 ^b	0 ^b	9 ^a	1.7
Healthy	0 ^{ns}	0 ^{ns}	5 ^{ns}	0 ^b	8 ^a	5 ^{ab}	1.7
Total likes	163	120	212	167	151	206	95.9
<i>Dislike comments (D)</i>							
Taste	20 ^{ns}	22 ^{ns}	17 ^{ns}	9 ^b	19 ^{ab}	24 ^a	13.4
Texture	10 ^b	34 ^a	6 ^b	4 ^b	24 ^a	7 ^b	10.3
Chewy	28 ^a	13 ^b	2 ^c	24 ^a	8 ^b	0 ^c	9.1
Bland	10 ^b	24 ^a	6 ^c	19 ^a	10 ^{ab}	2 ^b	8.6
Dry	14 ^a	5 ^{ab}	1 ^b	29 ^a	14 ^b	5 ^b	8.2
Appearance ^{ns}	12	9	13	8	8	2	6.3
Aroma ^{ns}	11	11	3	8	7	2	5.1
Too thin	9 ^{ns}	0 ^{ns}	0 ^{ns}	22 ^a	2 ^b	4 ^b	4.5
Hard	13 ^a	5 ^{ab}	0 ^b	11 ^a	6 ^{ab}	1 ^b	4.4
Aftertaste ^{ns}	4	5	7	3	5	11	4.2
Too greasy ^{ns}	6	8	4	5	2	4	3.5
Weak meat (taste)	2 ^{ab}	1 ^b	9 ^a	5 ^{ns}	2 ^{ns}	7 ^{ns}	3.1
Gristly ^{ns}	5	6	4	3	4	0	2.7
Too soft ^{ns}	0	0	15	0	0	5	2.4
Strong veg (taste) ^{ns}	0	0	7	0	0	13	2.4
Crumbly ^{ns}	0	5	3	0	3	3	1.7
Pale colour ^{ns}	3	5	1	0	4	0	1.6
Rubbery ^{ns}	5	2	1	2	1	0	1.3
Bitty ^{ns}	0	6	0	0	1	0	0.8
Total dislikes	152	161	99	152	120	90	93.6

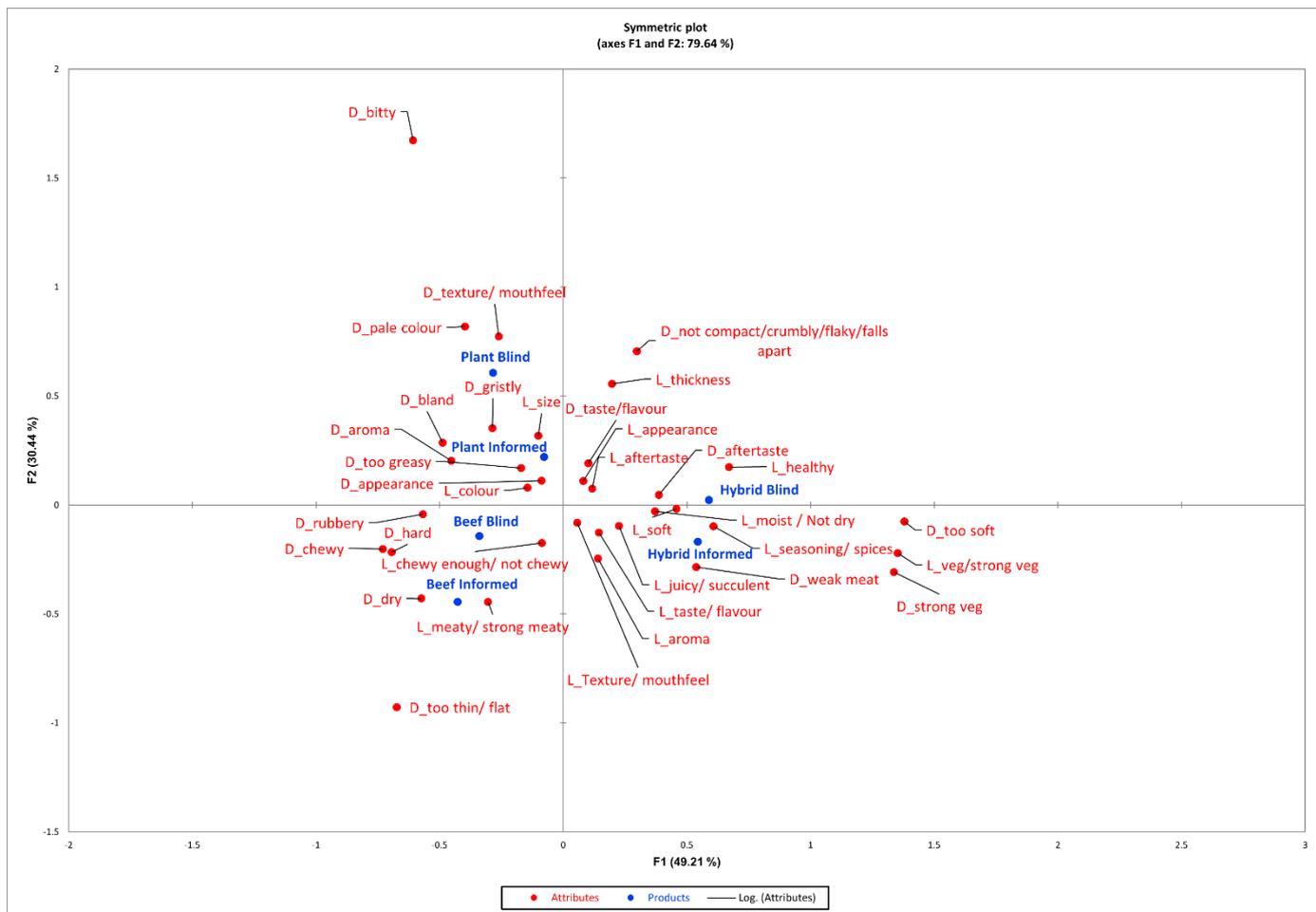
538 *Percentage of mentions in relation to the total number of like or dislike comments.

539 a,b,c Attributes with different letters, within the same blind or informed condition in a row,
 540 are significantly different ($p \leq 0.05$) according to Cochran's Q test McNemar (Bonferroni)
 541 post-hoc test.

3.6.3 Correspondence analysis (CA)

542 A CA on the comment's frequency was carried out to visualise the characterisation of a
 543 sample-condition, based only on the comments cited by at least 5% of the consumers.
 544 Figure 2 shows the CA based on the contingency table with burgers and main terms cited by
 545 consumers.
 546 consumers.

547 The first two dimensions of the CA represented 80% of the total variation. According to the
 548 comment analysis, samples were separated along the area into the same three groups as
 549 those formed by analysis of overall liking ratings under blind and informed conditions (Table
 550 2). Plant-based samples scored least for overall liking under blind and informed conditions,
 551 followed by the beef-based and then scoring highest, the hybrid-based samples. The less
 552 liked products are located towards the upper left quadrant and more liked products towards
 553 the lower right quadrant. Furthermore, the informed condition of the plant, beef and hybrid
 554 samples is placed further towards the liking direction, while the blind condition samples
 555 gravitate towards the disliking direction. The second dimension also separates the plant-
 556 based from the beef burgers.



557

558 Figure 32. Correspondence analysis on the contingency table with burger samples, conditions and
1 559 main comments cited by consumers. Blue circles represent samples and condition, and red circles
2 560 represent comments, L for likes and D for dislikes.

3
4 561 Analysing text comments gave us an insight into the consumers' own language for
5 562 describing the products and their drivers of liking and disliking. As in previous work (Ares et
6 563 al., 2010; Lahne, Trubek, & Pelchat, 2014; Symoneaux et al., 2012) comment analysis
7 564 revealed aspects from a consumer's perspective. Consumers described products with their
8 565 own vocabulary and identified attributes responsible for consumers' preference. For
9 566 example, for hybrid burgers, the most frequent like comments were "taste" and "juicy"
10 567 across blind and informed conditions. As for the most frequent term driving disliking, "taste"
11 568 elicited the most frequent comments across both conditions, although in less frequency
12 569 than liking comments. For disliking, while "too soft" and "appearance" were the following
13 570 most cited terms under blind condition, "strong vegetable taste" and "aftertaste" were the
14 571 following most recurrent terms under informed condition.

20 572 **4. Discussion and implications for industry and policy makers**

21
22 573 The results from this study arise a series of new insights about consumers' attitude towards
23 574 different alternatives to traditional meat products. In this section we discuss them in
24 575 relation to other results that emerged from previous studies on the topic of meat
25 576 alternatives and derive some implications for industries and policy makers.

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31 578 Interestingly, under the blind and the informed conditions hybrid burgers were the most
32 579 liked followed by beef and plant-based burgers, while consumers were expecting to prefer
33 580 beef burgers the most. These results are in line with Neville et al. (2017) who compared the
34 581 sensory acceptability of hybrid, meat and meat-free products and found no significant
35 582 difference between hybrid and full meat products, while meat-free products were less
36 583 accepted. Similarly, the hybrid burger scored higher than the beef and plant-based burger
37 584 for aroma liking. Analogue results emerged also from Tarrega, Rizo, Murciano, Laguna, and
38 585 Fiszman (2020) who looked at expected liking of beef burgers vs hybrids vs plant-based
39 586 burgers. They divided participants into "pro", "interm" and "anti" meat reduction. Both
40 587 "anti" and "interm" expected to like beef burgers significantly more than the other burgers,
41 588 while the "pro" group expected to like beef, hybrids, and plant-based burgers in a similar
42 589 way. These results are also similar to Neville et al. (2017) who found that "meaty flavour"
43 590 and "juicy" were the main driver for liking in beef burgers.

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49 591 On the other hand, the unmet expectations for plant-based burgers confirm the necessity
50 592 from manufacturers to develop products with enhanced sensory properties aiming at
51 593 replicating the conventional meat taste, as the current alternatives seem to yet fail on this
52 594 aspect and thus are poorly accepted by consumers. However, it is worth mentioning that
53 595 studies focusing on vegetarian and vegan consumers discovered that these segments of
54 596 people do not seek for conventional meat taste when purchasing meat alternatives and that
55 597 in most cases they even developed a disgust for meat (Fessler, Arguello, Mekdara, & Macias,
56 598 2003). Hence, it is vital for plant-based meat industries to first select their consumers' target

599 and then develop their products in accordance with their needs before launching their
600 products into the market.

601 In the CATA task, similar results emerged in relation to the consumers' sensory dislike of
602 plant-based meat burgers. However, because they were also associated with the 'healthy'
603 aspect, industries and policy makers are encouraged to promote these products by
604 emphasizing the benefits that they have compared to conventional meat products. The
605 former could use labels on the packaging of their products to provide customers with such
606 information, while the latter could promote initiatives to better educate people on this
607 matter. On the contrary, positive sensory associations emerged with hybrid meat products.

608 Results from the ranking task showed that the attribute "environmentally-friendly" scored
609 highest for plant-based burgers, followed by hybrid burgers and beef burgers. This suggests
610 that plant-based meat manufacturers should emphasize the lower environmental impact of
611 plant-based meat products compared to hybrid and conventional meat products to attract
612 consumers. On the other hand, policy makers should promote initiatives to better educate
613 consumers on this matter.

614 In terms of WTB and WTP, beef burgers scored higher than hybrid and plant-based meat
615 burgers, which is comparable to results from Tarrega et al. (2020) who found that most
616 consumers would buy the beef samples compared to the other burger options given (hybrid
617 or 100% plant-based).

618 However, the overall positive consumers' reaction towards hybrid meat products,
619 particularly from a sensory perspective, might help the shift towards a reduction in meat
620 consumption. In fact, the proportion of meat included in the hybrid meat products could be
621 gradually lowered in order to let consumers get used to a higher percentage of vegetables
622 over meat. To facilitate this process, it is important that companies continue doing co-
623 creation activities and sensory evaluations aimed at investigating consumers' preferences
624 for different plant-based sources to be associated with meat to increase acceptance. In the
625 future, multi-measurement approaches could also be used to better link sensory
626 evaluations, WTP and other important factors such as emotions, similarly to Jaeger et al.
627 (2017). The gradual increase of the plant-based portion in hybrid meat products could
628 consequently reduce the intake of meat and might also increase consumers' liking of plant-
629 based meat alternatives. At the same time, policy makers should educate consumers
630 disclosing the importance of preferring a plant-based over a meat-based diet, not only from
631 a health, but also from an animal welfare and environmental prospective.

632 **5. Conclusion**

633 This study aimed to compare for the first time the sensory quality of a beef burger vs a
634 hybrid burger and a plant-based burger in blind, expected and informed conditions. Results
635 show a significant effect of composition information on consumer acceptability, purchase
636 intent and WTP for the three burgers. Results are overall positive towards hybrid burgers, in
637 terms of overall acceptability, purchase intent, WTP and consumer comments. Hybrid meat
638 products could represent an effective way for consumers to lower their meat consumption
639 without compromising too much on the sensory quality and could represent a transition

640 product to a more plant-based diet. These results are valuable and should inform future
641 marketing, labelling and reformulation efforts of new hybrid meat product launches.

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